Appendix 8.3

Additional Supporting Analysis (TSD Chapter 5)

5.0 ADDITIONAL SUPPORTING ANALYSIS

This Chapter presents additional supporting analysis to the modeled 2018 visibility projections provided in Chapter 4. This supporting analysis may be used by the states in their RHR SIPs, along with their factor analysis, to assist in setting their 2018 RPGs for the worst 20 percent days and best 20 percent days.

5.1 Comparison of CENRAP 2018 Visibility Projections with Other Groups

2018 visibility projections for CENRAP and nearby Class I area have also been performed by the other RPOs. Thus, it is useful to compare the CENRAP 2018 visibility projections with those from the other RPOs as a quality assurance (QA) check and to foster confidence in the CENRAP modeling results.

5.1.1 Comparison of CENRAP, VISTAS, MRPO and WRAP Visibility Projections

The CENRAP 2018 Base G visibility projections were compared to the following other RPO visibility projections:

- VISTAS 2018 visibility projections based on their CMAQ 12 km 2002 annual modeling results for the 2002 Base G and 2018 Base G2a emissions scenarios.
- MRPO 2018 visibility projections based on their CAMx 36 km 2002 annual modeling for the Run 4 Scenario 1a (R4S1a) emissions scenario.
- WRAP 2018 visibility results based on their Plan02b and Base18b CMAQ 36 km modeling of the 2002 calendar year.

Figure 5-1 displays a DotPlot comparison of the four RPO visibility projections expressed as a percentage of achieving the 2018 URP point at CENRAP and nearby Class I areas. For the four CENRAP Class I areas just west of the Mississippi River in Arkansas and Missouri (CACR, UPBU, HEGL and MING), 2018 visibility projections are available from the CENRAP, VISTAS and MRPO RPOs. At HEGL, the three RPOs 2018 visibility projections are in close agreement with each other (estimated to achieve 99%, 101% and 95% of the 2018 URP point). The CENRAP and VISTAS 2018 visibility projections are also very close at the other three Arkansas-Missouri CENRAP Class I areas: CACR (112% and 116%), UPBU (109% and 112%) and MING (118% and 114%). But the MRPO 2018 visibility projections are approximately 12 to 25 percentage points lower than the CENRAP and VISTAS projections at these three Class I areas, with values of 97% to 100%. The reasons why the MRPO 2018 visibility projections are less optimistic than CENRAP and VISTAS are unclear. However, the MRPO focused on visibility projections at their northern Class I areas and likely did not use the latest CENRAP emission estimates. In addition, the CENRAP 2018 visibility projections included BART controls on several sources in CENRAP states not included in the MRPO projections. Such BART controls are even more important in those states not covered by CAIR.

For the Breton Island (BRET) Class I area, 2018 visibility projections are available from CENRAP and VISTAS. CENRAP estimates that BRET will achieve 94% of the URP point and VISTAS is slightly less optimistic with an 84% value. One potential contributor to this is that emissions from off-shore marine vessel emissions in the oil and gas production areas of the Gulf of Mexico are double counted in the VISTAS Base G modeling. As these emissions were assumed to remain unchanged between 2002 and 2018, the double counting of their emissions will result in stiffer RRFs than there should be and consequently less visibility benefits in 2018. This double counting also occurred in the CENRAP Base F modeling but was corrected in Base G. The double counting occurred because off-shore marine vessels were present in both the MMS off-shore oil/gas development inventory for the Gulf of Mexico and the VISTAS off-shore marine vessel inventory for the Pacific and Atlanta Oceans and the Gulf of Mexico. VISTAS intends to correct this double counting in their next round of modeling.

At the two northern Minnesota Class I areas (BOWA and VOYA), the MRPO 2018 visibility projections (93% and 92%) exhibit more visibility improvements than CENRAP's (69% and 53%). This is believed to be due to higher contributions to visibility impairment from Canada in the CENRAP modeling. Figure 5-2 displays the CENRAP 2002 Base F total SO2 emissions and their differences with the 2018 Base F SO2 emissions. The SO2 emissions in Alberta Canada appear to be much higher and more wide spread when compared to the other provinces in Canada and U.S. states. Also, there is a very large SO2 source in northern Manitoba (> 10^5 tons/year). The Alberta SO2 emissions may be overstated in the CENRAP modeling, which would overstate the Canadian contribution to visibility impairment. In the MRPO modeling, the western boundary of their modeling domain was east of the Rocky Mountains so did not include Alberta. CENRAP confirmed that the Alberta emissions and the source in Manitoba were present in the emissions provided by Canada.

At the VISTAS Mammoth Cave (MACA), Kentucky Class I area, VISTAS, CENRAP and the MRPO estimated that 2018 visibility for the worst 20 percent days will achieve, respectively, 122%, 123% and 102% of the 2018 URP point. The close agreement between the VISTAS (122%) and CENRAP (123%) 2018 visibility projections for MACA is encouraging. Why MRPO is 20 percentage points lower is unclear, but may be due to using earlier versions of the VISTAS and CENRAP emissions. The 2018 visibility projections at Sipsey (SIPS), Alabama estimated by VISTAS (127%) and CENRAP (130%) are also extremely close.

Both the CENRAP and WRAP 2018 visibility projections agree that the WRAP Class I areas fail to achieve the 2018 URP point by a wide margin, with values achieving only ~40% or less of the 2018 URP point. The CENRAP 2018 visibility projections agrees well with the WRAP values at Great Sands (GRSA), Colorado (18% vs. 15%), Badlands (BADL), South Dakota (24% vs. 31%), Theodore Roosevelt, North Dakota (15% vs. 11%) and Lostwood (LOST), Montana (11% vs. 14%). There is also reasonable agreement between CENRAP and WRAP 2018 visibility projections at Salt Creek (SACR), New Mexico (30% vs. 12%), Rocky Mountain (ROMO), Colorado (43% vs. 30%), and Wind Cave (WICA), South Dakota (24% vs. 6%). There are two WRAP Class I areas, White Mountains (WHIT) and Wheeler Peak (WEPE), where the WRAP 2018 visibility projections estimate that visibility will degrade for the worst 20 percent days (i.e., negative percent of achieving the 2018 URP point), whereas CENRAP estimates visibility improvements. The reasons for these differences are unclear.

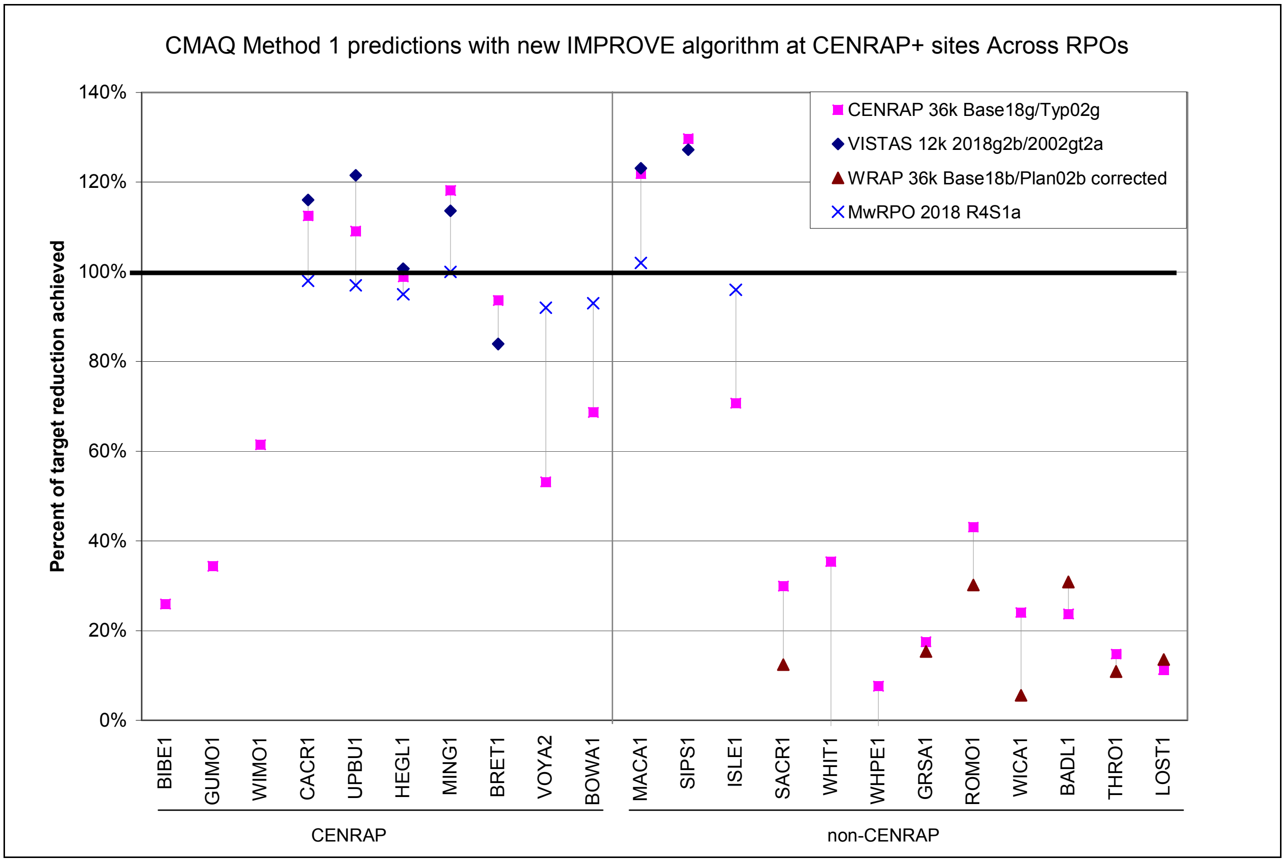


Figure 5-1. DotPlot comparing the CENRAP, VISTAS, MRPO and WRAP 2018 visibility projections expressed as a percentage of achieving the 2018 URP goal.

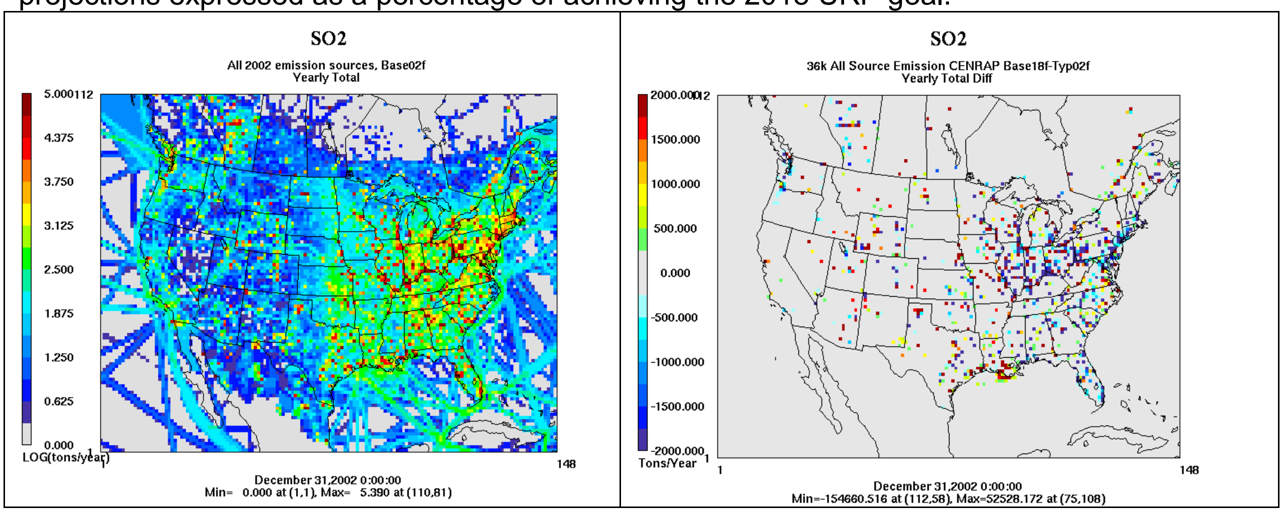


Figure 5-2. 2002 Base F SO2 emissions (left) as LOG10(tons/year) and differences in 2018 and 2002 Base F SO2 emissions (tons/year).

5.2 Extinction and PM Species Specific Visibility Projections and Comparisons to 2018 URP Point

It is useful to examine 2018 visibility projections by PM species to determine how each PM component of visibility is changing as both a diagnostic analysis of the visibility projections as well as whether species that are more associated with anthropogenic emissions (e.g., SO4 and NO3) are being reduced substantially compared to those that are not as influenced by anthropogenic emissions (e.g., Soil and CM). However, because deciview is the natural logarithm of total extinction, such comparisons can not be made using the deciview scale and must be made using extinction. The linear glidepath from which the 2018 URP points are derived are based on deciview, thus to examine corresponding glidepath using extinction the curvature associated with the linear deciview glidepath must be projected on the extinction glidepath.

5.2.1 Total Extinction Glidepaths

Figure 5-3 displays a total extinction based glidepath for Caney Creek that is based on the EPA default deciview linear glidepath counterpart shown in Figure 4-3a. That is, the deciview linear glidepath defined by the 26.36 dv Baseline Conditions at 2004 and the 11.58 dv Natural Conditions in 2064 is turned into extinction (Bext) [Bext = 10 exp(dv/10)] to create the curved extinction glidepath that exactly matches the linear deciview glidepath. Using the extinction curved glidepath the 2018 URP point is to reduced the 140.02 Mm^{-1} Baseline Conditions to 98.88 Mm^{-1} by 2018 (a 41.14 Mm^{-1} reduction). The modeled 2018 visibility projection in extinction is 97.54 Mm^{-1}, a 42.48 Mm^{-1} reduction which achieves 103% of the reduction needed to achieve the 2018 URP goal. Note that this compares with achieving 112% of the 2018 URP reduction point when using the deciview linear Glide Path. The percent of achieving the 2018 URP point using the linear deciview and curved extinction glidepaths will rarely be the same due to the logarithmic relationship between the two visibility metrics and the fact that averaging within and across years in the deciview calculations occur after the logarithms have been applied. The greater the difference in extinction across the worst 20 percent days in a year and averaged across the years in the 2000-2004 Baseline and the greater number of years available from the 2000-2004 Baseline may result in greater differences in the 2018 URP points using the linear deciview and the curved extinction glidepaths.

Appendix F contains total extinction curved glidepaths for all the CENRAP Class I areas and Figure 5-4 contains a DotPlot that compares the percent of achieving the 2018 URP point at each CENRAP Class I area using the 2018 Base G modeling results and the linear deciview and curved extinction glidepaths. At most CENRAP Class I areas the ability of the 2018 modeling results to achieve the 2018 URP point is the same using either the deciview or extinction glidepaths. There are some differences at GUMO, BOWA and VOYA Class I areas which are due to these Class I areas having more complete data during the 2000-2004 Baseline period and therefore more years in the Baseline than other Class I areas as well as having variations in extinction across the worst 20 percent days and years (Appendix F). In any event, the closeness of the ability of the model to achieve the 2018 URP point using either the extinction or deciview glidepath verifies the validity of the extinction based glidepaths and allows for the construction of PM species specific glidepaths in extinction to gain insight into how each component of extinction is being reduced to achieve a uniform rate of progress toward natural conditions in 2064.

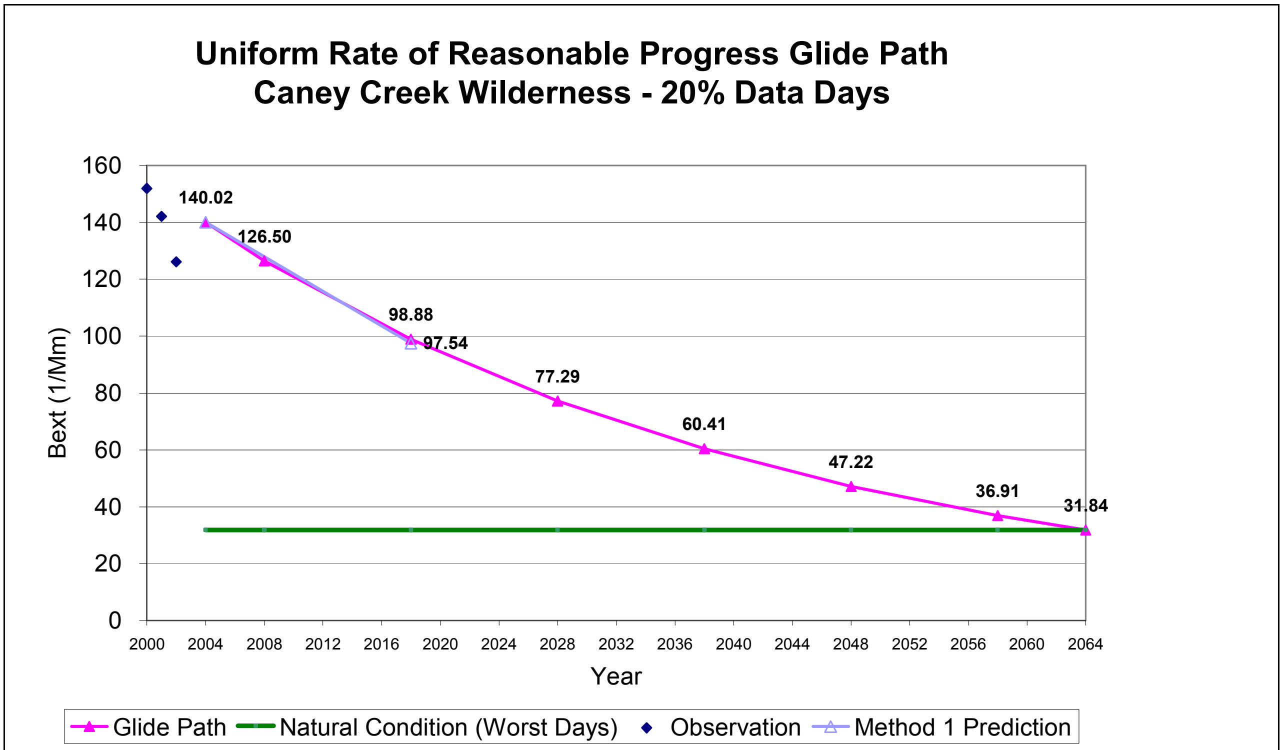


Figure 5-3. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

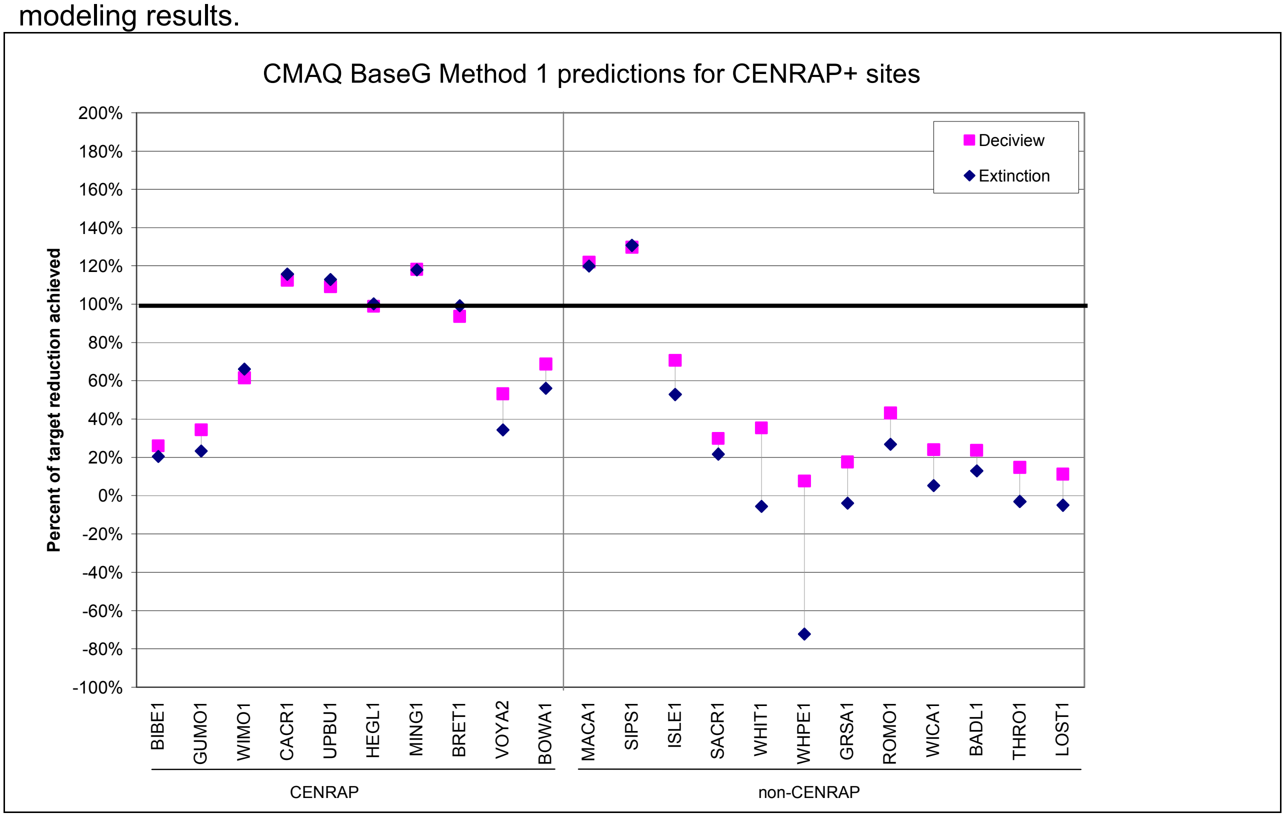


Figure 5-4. CMAQ 2018 Base G visibility projections and comparison of ability to achieve the 2018 URP point using the EPA default deciview and alternative total extinction Glidepaths.

5.2.2 PM Species specific Glidepaths

The VIEWS website (http://vista.cira.colostate.edu/views/) has posted PM species specific Natural Conditions based on the new IMPROVE equation. Using these PM species specific Natural Conditions and the curved extinction glidepaths we can evaluate how well visibility extinction achieves the 2018 URP point on a species-by-species basis. The PM species specific glidepaths are constructing using the a Baseline at 2004 by averaging the extinction for each PM species measured at the IMPROVE sites from the 2000-2004 5 year period and the Natural Conditions in 2064 from the VIEWS website. Points in the glidepath for the years in between 2004 and 2064 are constructed based on the relative differences in the 2004 Baseline and 2064 Natural PM species extinction such that the total extinction adds up to the same as on the extinction based glidepath (e.g., Figure 5-3 and Appendix F). As there are larger differences between the Baseline and Natural PM species extinction for some species, then the rate of improvement to achieve a species specific 2018 URP point will vary across PM species. For example, current Baseline extinction values for Soil and CM tend to be closer to Natural Conditions than extinction due to SO4 and NO3. Consequently the rate of progress to achieve the 2018 URP point for Soil and CM will be less than for SO4 and NO3.

Appendix F contains the PM species specific glidepaths compares them to the modeled 2018 projections for all CENRAP Class I areas. The species specific results for the CACR Class I area in Figure F-1 are reproduced in Figure 5-5. The modeled rate of SO4 and NO3 extinction reduction is greater than the PM species specific glidepaths and both achieve the species specific 2018 URP point by achieving 111% and 104% of the reduction needed to achieve the 2018 URP point. The modeled rate of extinction improvement at CACR for EC and OC is less than the species specific glidepath achieving only 65% and 75% of the reduction needed to achieve the species specific 2018 URP point. The PM species specific glidepath for Soil is flat because the Baseline and Natural Conditions (1.12 Mm^{-1}) are the same. This does not mean that anthropogenic emissions of Soil do not contribute on worst 20 percent days at CACR. It just points to a mismatch between the current set of worst 20 percent days and those in 2064 under Natural Conditions. The worst 20 percent days in 2064 under Natural Conditions will be dominated by wind blown dust days when Soil and CM may be higher than during the current set of worst 20 percent days that are dominated by SO4, NO3 and OMC. Thus, the Soil and CM glidepaths tend to be flatter and in some cases may even have an upward trend for some Class I areas (see Appendix F). Soil is projected to increase at CACR in 2018 so does not achieve its species specific URP point. Little reduction in CM is also seen by 2018. As discussed previously, this is due in part to a mismatch between the measured Soil and CM values at the IMPROVE monitor and the modeled Soil and CM species. In the model a large component of the Soil and CM in the inventory is due to paved and unpaved road dust. These emissions are directly related to Vehicles Miles Traveled (VMT). VMT is projected to increase in future-years resulting in increases in road dust emissions. At the IMPROVE monitor much of the Soil and CM measured is likely due to local dust events that are not simulated by the model using a 36 km grid resolution. Thus, the 2018 projections for Soil and CM are likely applying modeled changes due to road dust to local Soil and CM concentrations that in reality are likely natural and should remain unchanged in the future year. This is why alternative 2018 modeled projection approaches have been developed that assume that CM and CM and Soil are natural so remain unchanged in the future-year (see Section 5.5).

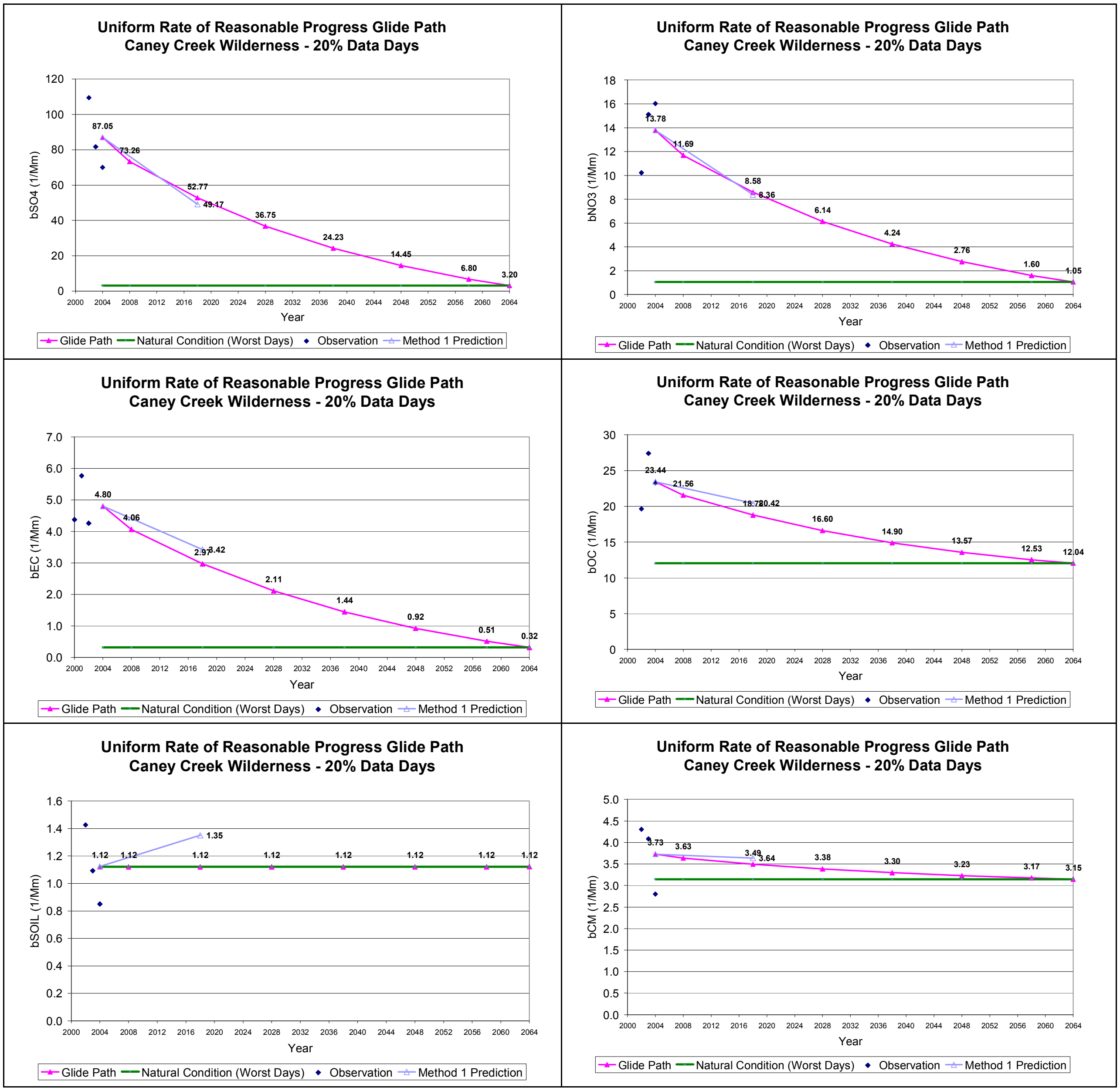


Figure 5-5. 2018 Visibility Projections and 2018 URP Glidepaths for SO4 (top left), NO3 (top right), EC (middle left), OMC (middle right), Soil (bottom left) and CM (bottom right) in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20 Percent Days using 2002/2018 Base G CMAQ 36 km modeling results.

Figure 5-6 displays a DotPlot that compares the 2018 projected total and PM species specific extinction with the 2018 URP point. These results show that SO4 is most frequently achieving its 2018 URP point at those Class I areas that achieve the deciview URP point. Reductions in NO3 and EC also sometimes achieve their species specific URP point.

There are some anomalies in the species specific projections and glidepaths that bear mention and point to areas where better understanding is needed. The increase in 2018 Soil projections is not an isolated incident at CACR and occurs at other CENRAP Class I areas. There are three CENRAP Class I areas that achieve the Soil specific 2018 URP goal (HEGL, BOWA and VOYA). An examination of these glidepaths and visibility projections reveals that the current Baseline Conditions Soil at these three Class I areas is actually less than the 2064 Natural Conditions so that the glidepath is an accent rather than reduction (Figures F-4g, F-5g and F-6g). In these three cases the 2018 URP point is to increase extinction and the fact that these three Class I areas achieve their 2018 URP point for Soil just means soil is increased more than needed. Clearly, the 2018 URP point for Soil is not very meaningful under these conditions. The current Baseline Conditions for OMC at BRET and BOWA is also less than the Natural Conditions resulting in anomalous glidepaths (Figure F-3e and F-4e).

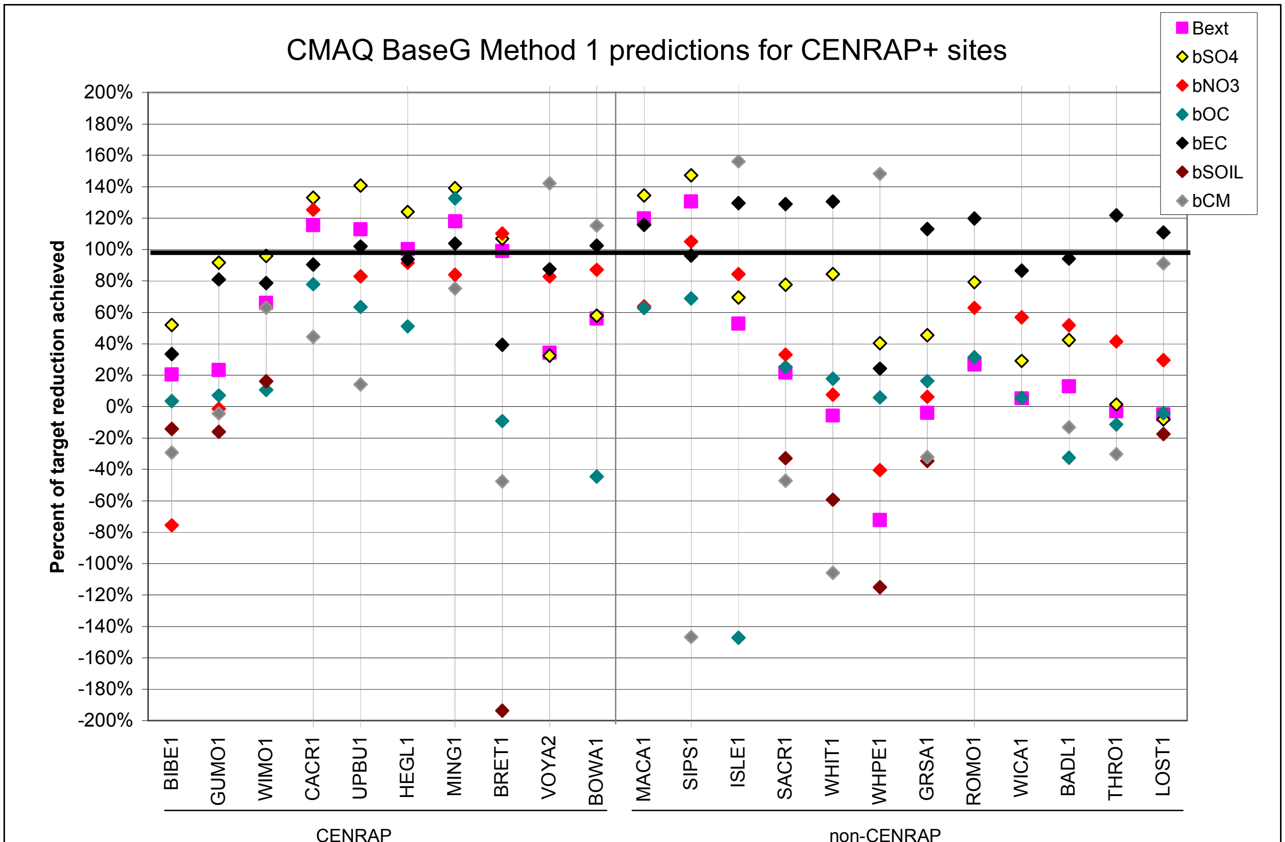


Figure 5-6. Ability of total and species specific 2018 visibility projections to achieve 2018 URP points.

5.3 Alternative 2018 Visibility Projection Software

The CENRAP 2018 visibility projections were made using software developed by the CENRAP modeling team. PM concentrations in the 36 km grid cells containing each of the Class I area IMPROVE monitoring sites were extracted using the UCR Analysis Tool. These modeling data were then ported into Excel spreadsheets that also include the filled RHR IMPROVE database available from the VIEWS website along with the EPA default Natural Conditions (EPA, 2003b). Excel macros are then used to perform the visibility projections using the EPA default procedures described in Chapter 4.

EPA is developing a Modeled Attainment Test Software (MATS) program that codifies the 8-hour ozone, $PM_{2.5}$ and visibility projection procedures given in EPA's latest air quality modeling guidance (EPA, 2007a). The June 2007 release of the beta versions of MATS is capable of performing 8-hour ozone and visibility projections; MATS is still under development for making $PM_{2.5}$ projections. The June 2007 beta versions of MATS was applied to the CENRAP 2002 and 2018 Base G 36 km CMAQ results and the resultant 2018 visibility projections were compared with the CENRAP values using the EPA default projection approach (see Chapter 4) at CENRAP and nearby Class I areas. The projected 2018 visibility estimated using the CENRAP and EPA MATS are shown in Table 5-1. The biggest difference in the MATS and CENRAP 2018 visibility projections are for the Boundary Waters (BOWA). Breton Island (BRET), and Mingo (MING) Class I areas where MATS produces no 2018 visibility projections. This is because there is insufficient capture of valid IMPROVE PM measurements within the 2000-2004 five-year baseline to generate three years of annual visibility estimates that is the minimum needed to develop the Baseline Conditions following EPA's guidance (EPA, 2003a). For the CENRAP projections, data filling was used to fill out the IMPROVE measurements with sufficient data so that Baseline Conditions could be calculated at these three Class I areas. At 14 of the remaining 17 Class I areas, the CENRAP and MATS 2018 visibility projections agree exactly to within a hundredth of a deciview. At the three sites that are different (BIBE, GUMO and ISLE) the difference is 0.01 dv, which is 0.06 percent or less. These differences are likely due to round off errors in the calculations and are not significant. These results verify the consistency with the CENRAP spreadsheet based and EPA MATS software for projecting future-year visibility estimates.

Table 5-1. Comparison of CENRAP and EPA MATS 2018 visibility projections at CENRAP and nearby Class I areas.

	2018 Visibility Projections		2000-2004 Baseline Conditions	
Site	MATS (dv)	CENRAP (dv)	MATS (dv)	CENRAP (dv)
BADL	16.53	16.53	17.14	17.14
BIBE	16.70	16.69	17.30	17.30
BOWA	NA	18.30	NA	19.58
BRET	NA	22.72	NA	25.73
CACR	22.48	22.48	26.36	26.36
GRSA	12.53	12.53	12.78	12.78
GUMO	16.36	16.35	17.19	17.19
HEGL	23.06	23.06	26.75	26.75
ISLE	19.35	19.36	20.74	20.74
LOST	19.27	19.27	19.57	19.57
MACA	25.60	25.60	31.37	31.37
MING	NA	23.71	NA	28.02
ROMO	13.17	13.17	13.83	13.83
SACR	17.25	17.25	18.03	18.03
SIPS	23.57	23.57	29.03	29.03
THRO	17.40	17.40	17.74	17.74
UPBU	22.52	22.52	26.27	26.27
VOYA	18.37	18.37	19.27	19.27
WHIT	13.14	13.14	13.70	13.70
WHPE	10.34	10.34	10.41	10.41
WICA	15.39	15.39	15.84	15.84
WIMO	21.47	21.47	23.81	23.81

NA = Not Available

5.4 PM Source Apportionment Modeling

The PM Source Apportionment Technology (PSAT) was used to obtain PM source apportionment by geographic regions and major source category for the CENRAP 2002 and 2018 Base E base case conditions. PSAT uses reactive tracers that operated in parallel to the CAMx host model using the same emissions, transport, chemical transformation and deposition rates as the host model to account for the contributions of user specified source regions and categories to PM concentrations throughout the modeling domain. Details on the formulation of the CAMx PSAT source apportionment can be found in the CAMx user's guidance (ENVIRON, 2006; www.camx.com).

5.4.1 Definition of CENRAP 2002 and 2018 PM Source Apportionment Modeling

PSAT calculated PM source apportionment for user defined source groups. Source groups are usually defined by specifying a source region map of geographic regions where source contributions are desired and providing source categories as input so that source group would consist of a geographic region plus source category (e.g., on-road mobile source emissions from Oklahoma). Although other source group configurations and even individual sources may be specified. For the CENRAP PSAT application, a source region map was used that divided up the modeling domain into 30 geographic source regions as shown in Figure 5-7. The 2002 and 2018 emissions inventories were divided into six source categories. The 30 geographic source regions consisted of CENRAP and nearby states, with Texas divided into 3 regions, remainder of the western and eastern States, Gulf of Mexico, Canada and Mexico. The six source categories that were separately tracked in the PSAT PM source apportionment modeling were:

- Elevated point sources;
- Low-level point sources (i.e., point source emissions emitted into layer 1 of the model);
- On-Road Mobile Sources;
- Non-Road Mobile Sources;
- Area Sources; and
- Natural Sources.

Natural Sources included biogenic VOC and NOx emissions from the BEIS3 biogenic emissions model, emissions from wildfires and emissions from wind blown dust due to non-agriculture land use types.

PM source apportionment in PSAT is available for five families of PM tracers: (1) Sulfate; (2) Nitrate and Ammonium; (3) Secondary Organic Aerosols (SOA); (4) Primary PM; and (5) mercury. The CENRAP PSAT 2002 and 2018 applications used three of the PSAT families of tracers and did not use the SOA and mercury families. For SOA, the standard CAMx model output was used that partitions SOA into an anthropogenic (SOAA) and biogenic (SOAB) components.

The PSAT results were extracted at the CENRAP and nearby Class I areas and the contributions for the average of the worst 20 percent and best 20 percent days were processed. A PSAT Visualization Tool was developed that can be used by States, Tribes and others to generate displays of the contributions of source regions and categories to visibility impairment for the average of the worst 20 percent and best 20 percent days at each CENRAP and nearby Class I areas.

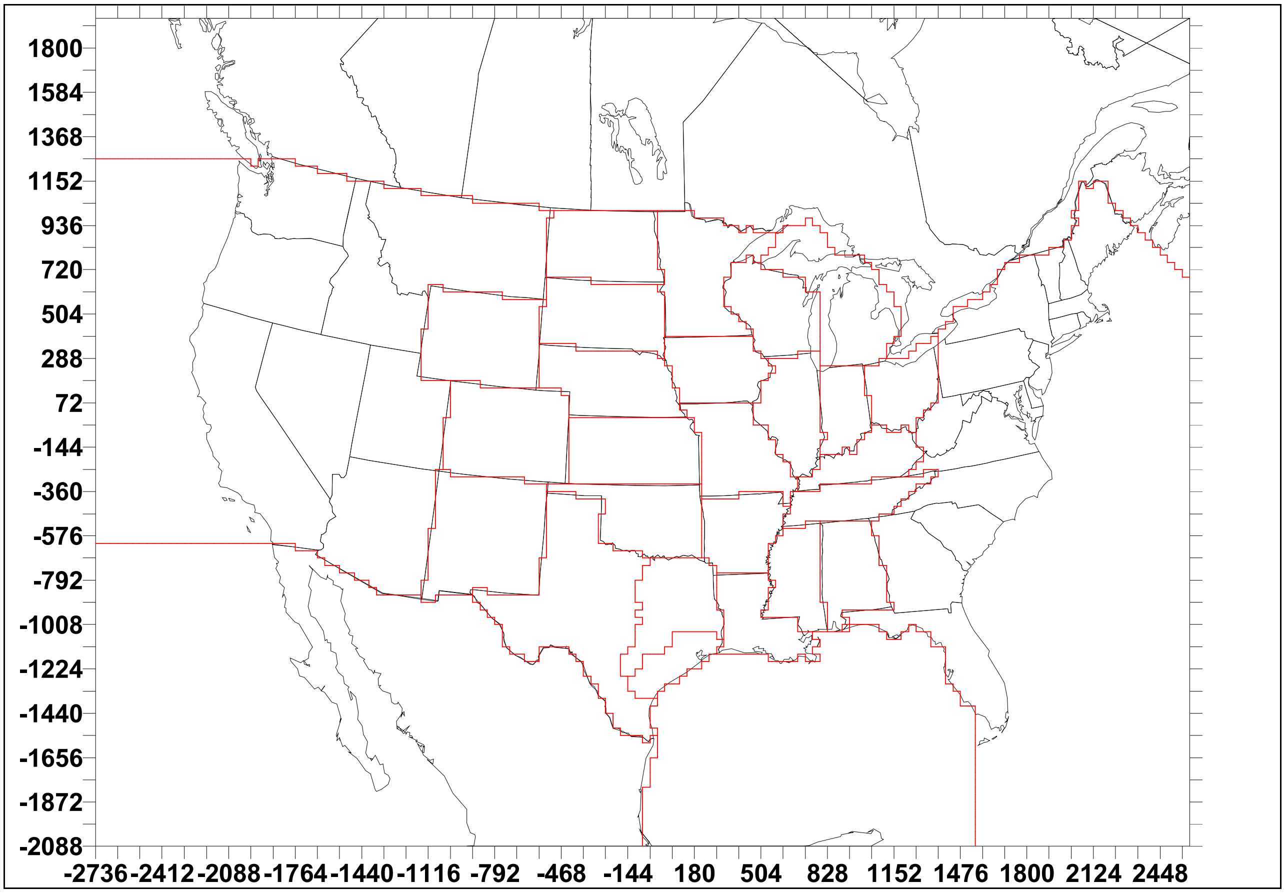


Figure 5-7. 30 source regions used in the CENRAP 2002 and 2018 CAMx PSAT PM source apportionment modeling.

5.4.2 CENRAP PSAT Visualization Tool

The PSAT Visualization Tool allows CENRAP States, Tribes and others to visualize the CENRAP 2002 and 2018 PSAT modeling results and identify which source regions, categories and PM species are contributing to visibility impairment at Class I areas for the average of the worst 20 percent and best 20 percent visibility days. The Visualization Tool is currently available on the CENRAP website (http://www.cenrap.org) under Projects. The Tool can generate bar charts of source contributions at Class I areas. It can be run in a receptor oriented mode where it identifies the contributions of PM species and source regions and categories to visibility impairment on the worst and best 20 percent days. It can also be run in a source oriented mode to examine an individual source region's (State's) contribution to visibility impairment at downwind Class I areas on the worst and best 20% days. The original IMPROVE equation is used to convert the PM species concentrations to extinction.

There are 14 air quality analysis metrics in the Tool:

> W20% Modeled Bext: The source region, source category and PM species contributions to the extinction (Bext) at a Class I area estimated by the model averaged across the worst 20 percent days in 2002.

W20% Projected Bext: The source region, source category and PM species contributions to the extinction (Bext) at a Class I area projected by the model averaged across the worst 20 percent days in the 2000-2004 Baseline.

W20% Modeled USAnthro: The source region, source category and PM species contributions to the extinction (Bext) at a Class I area for just U.S. anthropogenic emission source categories estimated by the model averaged across the worst 20 percent days in 2002.

W20% Projected USAnthro: The source region, source category and PM species contributions to the extinction (Bext) at a Class I area for just U.S. anthropogenic emission source categories projected by the model averaged across the worst 20 percent days in the 2000-2004 Baseline.

Emissions: Emissions by source region, source category and PM precursor. Precursors include SOx, NOx, primary organic aerosol (POA), primary elemental carbon (PEC) other primary fine particulate (FCRS+FPRM) and coarse mass (CCRS+CPRM). Emissions for four days have been extracted and implemented in the Tool.

Control Effectiveness: Control effectiveness is defined as the PM contribution divided by the emissions of the primary precursor. For example the SO4 contribution divided by the SO2 emissions.

Visualization Tool results are available for visibility contributions on both an absolute (Mm^{-1}) and percentage basis. When looking at contributions at a given Class I area, contributions can be examined in terms of PM species, source regions and/or source categories. Results are available for both the current year (2002 modeled or 2000-2004 projected) and future year (2018).

5.4.3 Source Contributions to Visibility Impairment at Class I Areas

Appendix E displays example contributions of PM species, source regions and source categories to visibility impairment for the worst and best 20 percent days at the CENRAP Class I areas. Some of the results from Figure E-1 for the CACR Class I area are reproduced in Figures 5-8, 5-9 and 5-10 below.

5.4.3.1 Caney Creek (CACR) Arkansas

2002 visibility impairment for the worst 20 percent days at CACR is primarily due to SO4 from elevated point sources that contributes over half (66.3 Mm^{-1}) of the total extinction of 118.8 Mm^{-1} (Figure E-1a and 5-8 left). By 2018 the total extinction at CACR for the worst 20 percent days is reduced by approximately a third (38.5 Mm-) which is due primarily to reductions in SO4 extinction from elevated point sources (from 66.3 to 37.3 Mm^{-1}) as well as reductions in visibility impairment from on-road and non-road mobile sources. Even with such large reductions in 2018, extinction due to elevated point sources is still the highest contributor to visibility impairment on the worst 20 percent days contributing over half (41.8 Mm^{-1}) of the total extinction on 2018 of 80.3 Mm^{-1}, with area sources the next most important source category contributing 16.0 Mm^{-1}.

The geographic source apportionment for the worst 20 percent says at CACR is shown in Figures 5-9, E-1c and E-1d. Elevated point sources from the eastern source region is the largest contributor in 2002 contributing almost 18 Mm^{-1} that is reduced by over a factor of three in 2018 to approximately 5 Mm^{-1}. By 2018 Arkansas is the largest contributor to extinction on the 20 percent worst days followed by East Texas, the large East region and then SOA due to biogenic sources. Figures E-1e ranks the source group contributions to extinction on the worst 20 percent days at CACR with Elevated Point Sources from East Texas being the highest contributor to total extinction, similar results are seen when examining extinction at CACR for the worst 20 percent days due to just SO4 and NO3 (Figure E-1f).

For the best 20 percent days at CACR (Figures 5-110, E-1g-j), SO4 is still a major contributor but no where near as dominate as the worst 20 percent days and elevated point is still the largest contributing source category Local contributions from within Arkansas contribute the most to the average of extinction across the best 20 percent days at CACR.

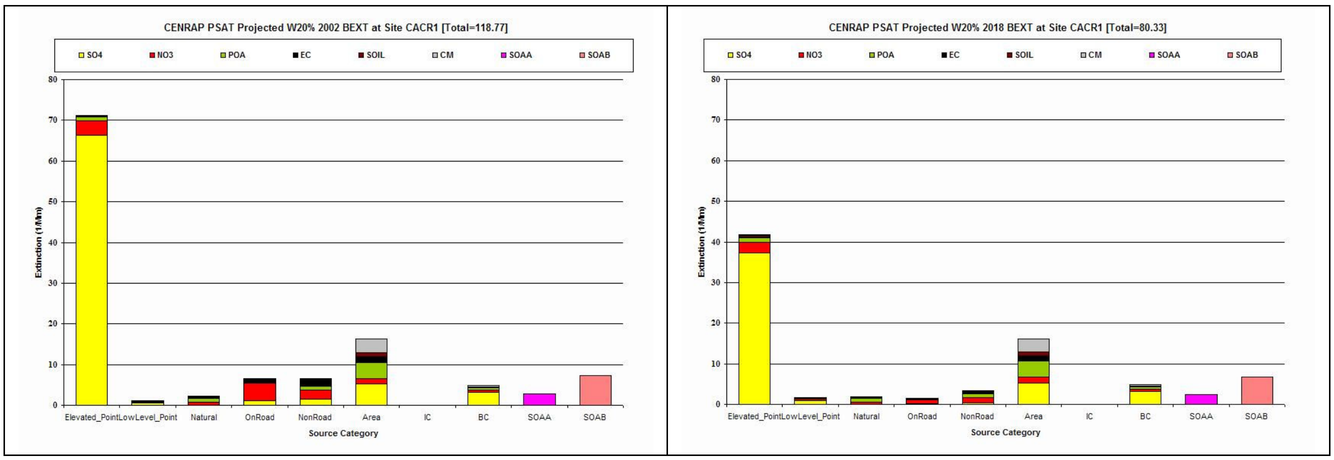


Figure 5-8. PSAT source category by PM species contributions to the average 2000-2004 Baseline and 2018 projected extinction (Mm^{-1}) for the worst 20 percent visibility days at Caney Creek (CACR), Arkansas.

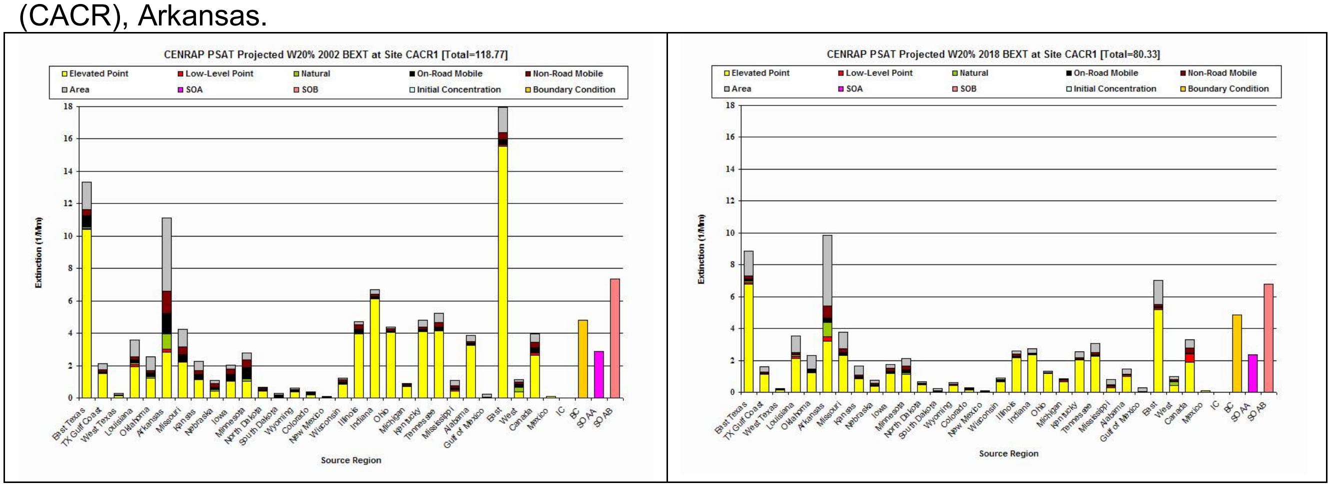


Figure 5-9. PSAT source region by source category contributions to the average 2000-2004 Baseline and 2018 projected extinction (Mm^{-1}) for the worst 20 percent visibility days at Caney Creek (CACR), Arkansas.

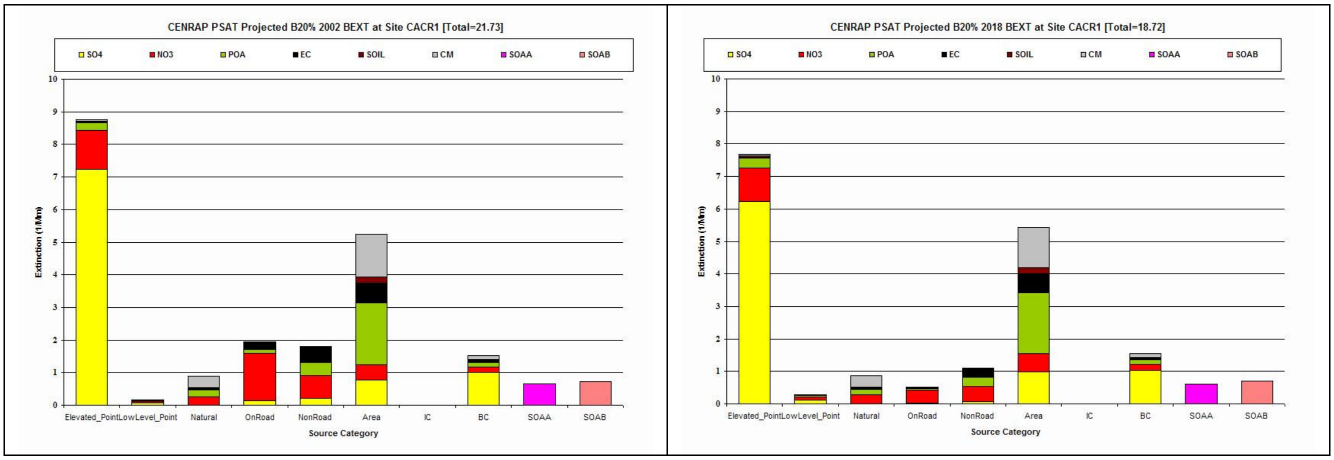


Figure 5-10. PSAT source category by PM species contributions to the average 2000-2004 Baseline and 2018 projected extinction (Mm^{-1}) for the best 20 percent visibility days at Caney Creek (CACR), Arkansas.

5.4.3.2 Upper Buffalo (UPBU) Arkansas

The contributions to extinction on the worst 20 percent days at UPBU (Figure E-2) is similar to CACR only with less contributions from East Texas and more from Missouri, Illinois and Indiana. By 2018 the top five largest contributing source groups to the average extinction on the worst 20 percent days are ranked as follows: Arkansas Elevated Point; SOA from biogenics; Boundary Conditions, East Elevated Points, and Illinois Elevated Points (Figure E-2e). On the best 20 percent days at UPBU visibility impairment is primarily due to Arkansas and adjacent states Oklahoma, Missouri, and Kansas).

5.4.3.3 Breton Island (BRET) Missouri

Visibility impairment for the worst 20 percent days at Breton Island is primarily (69%) due to elevated point sources that contribute 77.7 Mm^{-1} out of a total of 122.2 Mm^{-1} (Figure E-3a). Although the contribution of elevated point sources is reduced substantially by 2018, they still contribute over half of the total extinction (101.1 Mm^{-1}) on the worst 20 percent days at BRET (Figure E-3b). The top five contributing source groups to 2018 visibility impairment at BRET for the worst 20 percent days are: Louisiana Elevated Point Sources; Boundary Conditions; East Elevated Point Sources; Gulf of Mexico Area Sources and Louisiana Area Sources. Gulf of Mexico Area sources includes off shore shipping and oil and gas development emissions; note that for the PSAT simulation the off-shore marine shipping emissions were double counted which was corrected in the Base G emission scenarios used in the visibility projections discussed in Chapter 4.

5.4.3.4 Boundary Waters (BOWA) Minnesota

As seen for the other Class I areas, elevated point sources contribute the largest amount (47%) to visibility impairment at BOWA for the worst 20 percent days in 2002 (Figure E-4a). However, unlike many of the other Class I areas, there is little reductions (~10%) in the elevated point source contributions going from 2002 (29.0 Mm^{-1}) to 2018 (26.2 Mm^{-1}) (Figures E-4a and E-4b). This is because there is a slight increase in the contributions of elevated point sources in Minnesota from 2002 to 2018 (Figures E-4c and E-4d) that is the highest contributing source group (Figure E-4e). Note that the 2018 emission scenario includes growth and CAIR controls but no BART controls. For the best 20 percent days, the largest contributing source group by far is Boundary Conditions (i.e., global transport) followed by Minnesota and Canada (Figures E-4g-j).

5.4.3.5 Voyageurs (VOYA) Minnesota

Results for VOYA are similar to BOWA with Minnesota, Canada and Boundary Conditions contributing the most to visibility impairment on the worst and best 20 percent days (Figure E-5).

5.4.3.6 Hercules Glade (HEGL) Missouri

Elevated point sources contribute over half to the total extinction for the worst 20 percent days at HEGL in 2002 (Figure E-6a) and E-6b). Going from 2002 to 2018 the contributions due to elevated point sources, on-road mobile and non-road mobile are reduced substantially, but the contributions due to the other sources remain unchanged. The largest source group contributing to visibility impairment on the worst 20 percents days is area sources from Missouri in both 2002 and 2018. Since area emissions are not reduced much and Missouri elevated point sources are also not reduced (IPM assumed Missouri CAIR sources would buy credits) then the Missouri contributions is only reduced a little going from 2002 to 2018 (Figures E-6c and d). However, the contributions due to the East, Illinois and Indiana are reduced substantially. Missouri is by far the largest contribution to visibility impairment at UPBU on the best 20 percent days as well (Figures E-6h through E-6j).

5.4.3.7 Mingo (MING) Missouri

The substantial improvements in visibility impairment at MING for the worst 20 percent days from 20002 (141 Mm^{-1}) to 2018 (96 Mm^{-1}) is primarily due to reductions in $SO4$ from non-Missouri elevated point sources (Figures E-7a through E-7d). Even so, with the exception of the top contributing Missouri area sources the largest contributing source groups to 2018 visibility impairment for the worst 20 percent days are still elevated point sources from several CAIR states (Illinois, Indiana, Missouri, East; Figure E-7e). Missouri is the largest contributor to visibility on the best 20 percent days followed by Boundary Conditions and Illinois (Figure E-7i-j).

5.4.3.8 Wichita Mountains (WIMO) Oklahoma

Elevated point sources are the largest contributors to visibility impairment on the worst 20 percent days at WIMO in both 2002 and 2018 (Figures E-8a-b). East Texas followed closely by Oklahoma are the largest contributing source regions in 2002, but by 2018 the reverse is true (Figures E-8c-d). By 2018 the largest contributing source group to visibility impairment on the worst 20 percent days at WIMO is global transport (i.e., boundary conditions) followed by Oklahoma Area Sources and East Texas Elevated Point sources (Figure E-8e). Oklahoma Area Sources are also by far the largest contributor to visibility impairment on the best 20 percent days at WIMO (Figures E-8g-j).

5.4.3.9 Big Bend (BIBE) Texas

Elevated point sources (~17 Mm^{-1}) followed by Boundary Conditions (~12 $Mm^{-}1$) are the largest contributions to total extinction (46 Mm^{-1}) on the worst 20 percent days at BIBE in 2002 (Figure E-9a). In 2018 there is very little (~2 Mm^{-1}) reduction in the contributions of elevated point sources and no reductions in global transport resulting in little reductions (~7%) in visibility impairment on the worst 20 percent days from 2002 (46 Mm^{-1}) to 2018 (43 Mm^{-1}). This is due to the extremely large contributions of emissions from Mexico in both 2002 (Figure E-9c) and 2018 (Figure E-9d). In fact, the four highest contributing source groups to visibility impairment at BIBE for the worst 20 percent days are assumed to be unchanged from 2002 to 2018: Boundary Conditions, Mexico Elevated Points, West Texas Natural and Mexico Natural (Figure E-9e). For the best 20 percent days at BIBE, West Texas, Mexico and Boundary Conditions are the highest three contributors to visibility impairment (Figures E-9g-j).

5.4.3.10 Guadalupe Mountains (GUMO) Texas

The large contribution of CM to visibility impairment at GUMO is clearly evident in the source apportionment modeling results (Figures E-10a-b). These sources are about evenly divided in the modeling between natural sources and area sources. Since these source categories are not reduced in the future year then there is little reduction in extinction from 20002 to 2018 (50 to 45 Mm^{-1}) and what reductions there are come from Elevated Point Sources. Sources in West Texas, Mexico, Boundary Conditions and New Mexico are the largest contributing source regions for both the worst 20 percent days (Figure E-10c-e) and best 20 percent days (Figures E-10g-j).

5.5 Alternative Visibility Projection Procedures

In this section we analyze several alternative visibility projection procedures from the EPA's default approach (EPA, 2007a) used in Chapter 4.

5.5.1 Treatment of Coarse Mass and Soil

As noted previously, much of the coarse mass (CM) and, to a lesser extent, Soil measured at the IMPROVE monitor is likely due to local wind blown dust that is natural in origin and not captured by the model. Consequently, even using the modeling results in a relative sense with the RRFs may not be appropriate for projecting CM and Soil. If CM and Soil are in fact local impacts due to wind blown dust from natural lands then it would be appropriate to assume they are natural and hold them constant from the 2000-2004 Baseline to 2018. This is probably certainly appropriate for the CM because CM is primarily due to fugitive dust and it has a very short transport distance that is subgrid-scale to the model. In fact the model evaluation discussed in Chapter 3 and Appendix C clearly shows a large under-prediction bias for CM that is likely due to local fugitive dust impacts at the IMPROVE monitor. For Soil this is less clear as fine particles can be transported over longer distances and is produced by anthropogenic sources, such as combustion and road dust, as well as natural sources. We initially performed two CM and Soil sensitivity tests, one where CM was assumed to be natural and remain unchanged from the 2000-2004 Baseline (i.e., set the RRF for CM equal to 1.0). The second sensitivity test assumed both CM and Soil were natural so set RRFs for both of them to 1.0. One comment on these sensitivity test was that we know that some of the Soil is likely anthropogenic in origin. So it was suggested to subtract the 2002 base case modeled Soil from the observed values for the 2002 worst 20 percent days and assume that the remainder (if any) was natural so hold the rest of the Soil constant in 2018 and add to the 2018 modeled Soil values.

The results of the CM and Soil visibility projection sensitivity analysis are shown in the DotPlot in Figure 5-11. The CM and Soil visibility projection sensitivity analysis has little effect on the 2018 visibility projections at the CENRAP Class I areas. Even GUMO, which has a large CM and Soil component, shows very little sensitivity. This is probably because the CM at GUMO is likely dominated by wind blown dust that was assumed constant from 2002 to 2018 so the EPA default RRF is near 1.0 anyway. Some larger sensitivity is seen at several WRAP Class I areas. It is encouraging that CENRAP 2018 visibility projections are not sensitive to the CM and Soil components of the modeling which are highly uncertain.

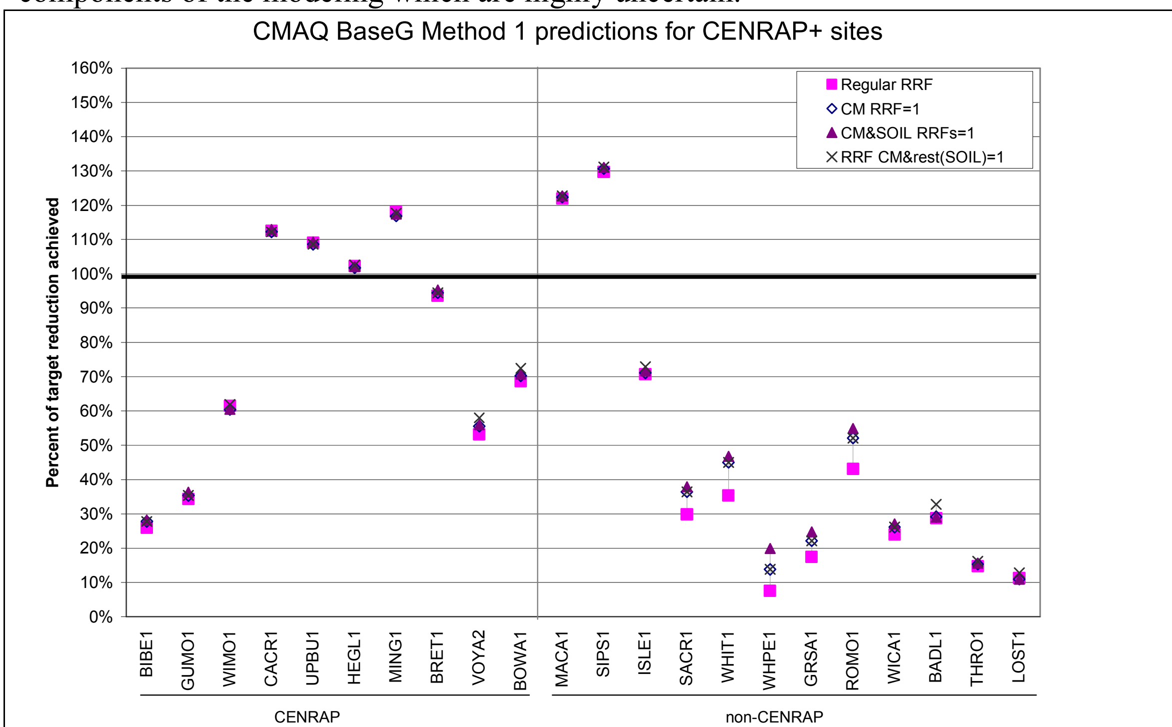


Figure 5-11. Sensitivity of 2018 visibility projections to various methods that assume all CM, all CM and Soil and all CM and part of the Soil is natural.

5.6 Alternative Model

The CAMx model was also run for a 2002 and 2018 base case scenarios with earlier versions of the CENRAP emissions than the final CMAQ 2002 Base G modeling. The CAMx 2002 and 2018 output was processed the same way that the CMAQ results were to generate 2018 visibility projections at the CENRAP and nearby Class I areas that were compared with the 2018 URP point. Figure 5-12 summarizes the CAMx 2018 visibility projections in a DotPlot, which can be compared with the CMAQ results shown in Figure 5-11. The CMAQ and CAMx 2018 visibility projections are remarkably similar. The four Arkansas and Missouri Class I areas are projected to achieve the 2018 URP point by almost the exactly same amount by the two models. The two Texas Class I areas are projected to come up short of achieving the 2018 URP point by the same amount by the two models. The largest differences are seen at BRET, and to a lesser extent BOWA and VOYA. At BRET the CAMx 2018 visibility projections are much less optimistic (< 80%) in achieving the 2018 URP point than CMAQ (> 90%). And CMAQ is slightly less optimistic than CAMx in achieving the 2018 URP point for the two northern Minnesota Class I areas. The reasons for these differences are unclear but could be partially due to the emissions updates in the final CMAQ Base G run that included eliminating the double counting of off-shore marine emissions in the Gulf of Mexico that was present in the CAMx simulation, which makes it more difficult to get visibility improvements at BRET since it is influenced by sources in the Gulf. Corrections to stack parameters for Canadian point sources were also made for the final Base G. The general close agreement of the CAMx 2018 visibility projections to the final CMAQ values is encouraging and good QA check.

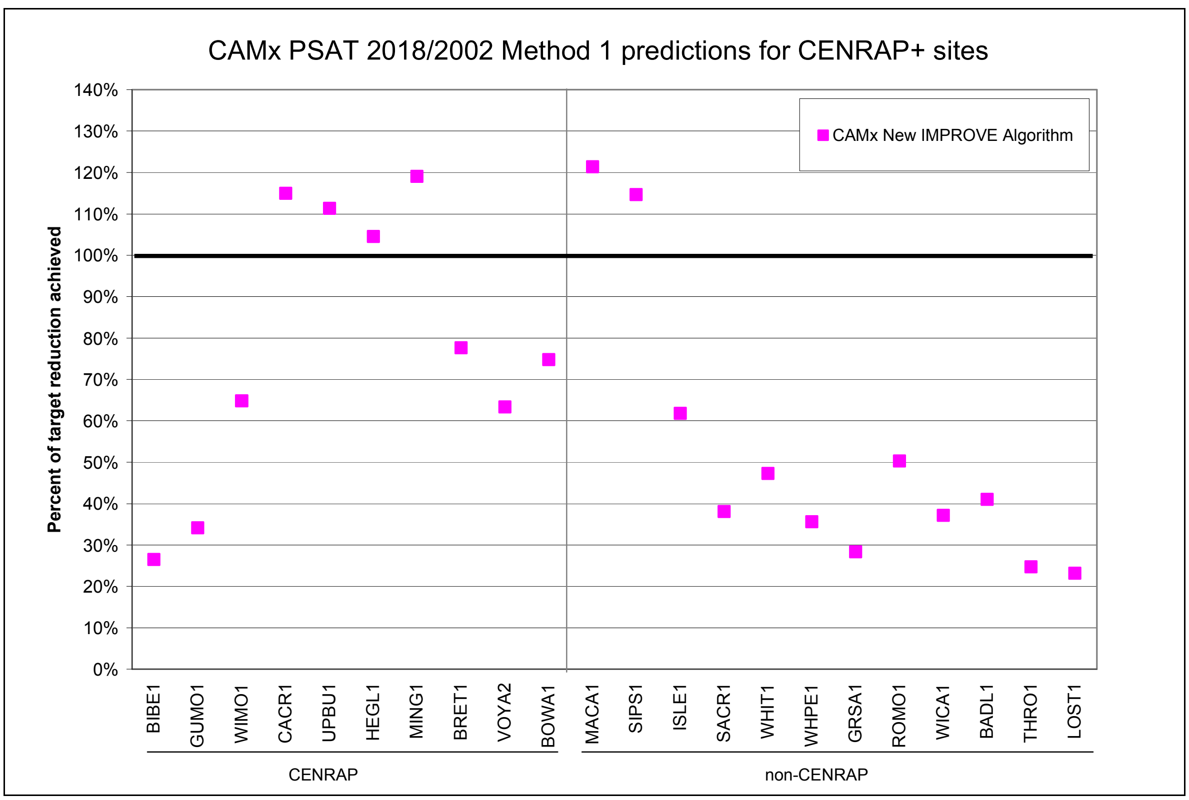


Figure 5-12. Comparison of CAMx 2018 visibility projections with 2018 URP points for CENRAP and nearby Class I areas.

5.7 Effects of International Transport on 2018 Visibility Projections

As seen in the PM source apportionment modeling discussed in Section 5.4, there is significant contributions of international sources to visibility impairment at many CENRAP Class I areas for the worst 20 percent days. With the exception of Canada, where we used a year 2000 inventory for the 2002 base case modeling and a 2020 inventory for the 2018 inventory, international sources were assumed to be constant between 2002 and 2018. Thus, Class I areas that are heavily impacted by contributions of international transport will have a difficult time achieving the 2018 URP point since international sources are assumed to remain constant. The CAMx PSAT runs discussed previously provide a framework for quantitatively assessing the contributions of international transport to the visibility projections and whether reasonable progress toward natural conditions is being achieved in the 2018 modeling.

There are several source regions (Figure 5-7) and types in the PSAT modeling that include international sources:

- Mexico Anthropogenic Sources (assumed all international);
- Canada Anthropogenic Sources (assumed all international);
- Gulf of Mexico (assumed all U.S. sources);
- Pacific and Atlanta Ocean (assumed all U.S. sources); and
- Boundary Conditions (assumed half international and half natural sources).

Although it can be argued that Mexico and Canada are not truly international due to the presence of numerous U.S. corporations in Mexico along with free trade among the two countries, states and federal government have no jurisdiction to regulate industry in these two countries so they are considered international in these calculations. The Gulf of Mexico includes off-shore oil and gas production facilities, support vessels and aircraft and off-shore marine shipping. Given that emissions from the oil and gas production can be regulated by the U.S., then the Gulf of Mexico is not considered an international source. Emissions from off-shore shipping in the Pacific and Atlantic Oceans are also currently not regulated by the U.S. government. However, there are current efforts to apply some regulations to these emissions so for these calculations they were not assumed to be international sources. Finally, the Boundary Conditions (BCs) for the CENRAP modeling were generated from a 2002 simulation of the GEOS-CHEM global chemistry model and held constant in 2018. These BCs would include contributions from international sources as well as natural sources, so need to be split. For the sensitivity calculations discussed below we assumed that the BCs were half due to natural and half due to international sources. This results in international sources being defined as follows:

International Contribution = Mexico Anthro + Canada Anthro + ½ BCs

Two methods were examined to see what the effects of international sources on 2018 visibility projections and a Class I areas ability to achieve the 2018 URP point:

<u>Elimination of International Contributions to 2018 Visibility Projections</u>: In this method the contribution of international emissions is taken out of the 2018 visibility projections and examined to see whether the new visibility projection achieves the URP point. If so, then international sources are hindering a Class I area in achieving the 2018 URP point, which suggests that the 2018 URP point is not a reasonable value for an RPG.

Visibility Projections and Glidepaths Based on Controllable Visibility Impairment: The second method would look at the visibility projections for just the U.S. controllable portion of the visibility impairment. The glidepath end point in 2064 would be to eliminate the U.S. man-made contributions to visibility impairment on the worst 20 percent days.

5.7.1 Elimination of International Contributions to 2018 Visibility Projections

This method was also discussed in a recent technical brief prepared by the Electric Power Research Institute (EPRI), only in EPRI's analysis they used results from a global chemistry model and VISTAS CMAQ runs with no global anthropogenic emissions (EPRI, 2007). Thus, before discussing our results of this analysis using PSAT, we discuss EPRI's analysis.

5.7.1.1 EPRI's Analysis of Effects of International Contributions

EPRI has funded Harvard University to perform annual simulations of the GEOS-Chem global chemistry model for simulations with and without non-U.S. anthropogenic emissions to determine the contributions of international transport to PM and visibility. The EPRI Harvard GEOS-Chem simulations were performed for 2001. Figure 5-13 and 5-14 compare the annual average ammonium sulfate, ammonium nitrate organic mass carbon (OMC, also called OCM) and elemental carbon (EC) due to the GEOS-Chem global modeling and the CAMx PSAT source apportionment modeling. The similarity of the results for ammonium sulfate is remarkable (Figure 5-13). Both methods estimate that the annual average ammonium sulfate contribution due to international sources ranges from 0.4 to 1.0 $\mu g/m^3$ across the Class I areas. There is less agreement between the two methods for ammonium nitrate due in part to a CAMx overestimation issue that is likely due in part to how ammonia emissions were classified as being anthropogenic or not in the no U.S. anthropogenic emissions simulations (Figure 5-14). Better agreement is seen between the two methods international contributions of OMC and EC, although CAMx estimates higher contributions than GEOS-Chem.

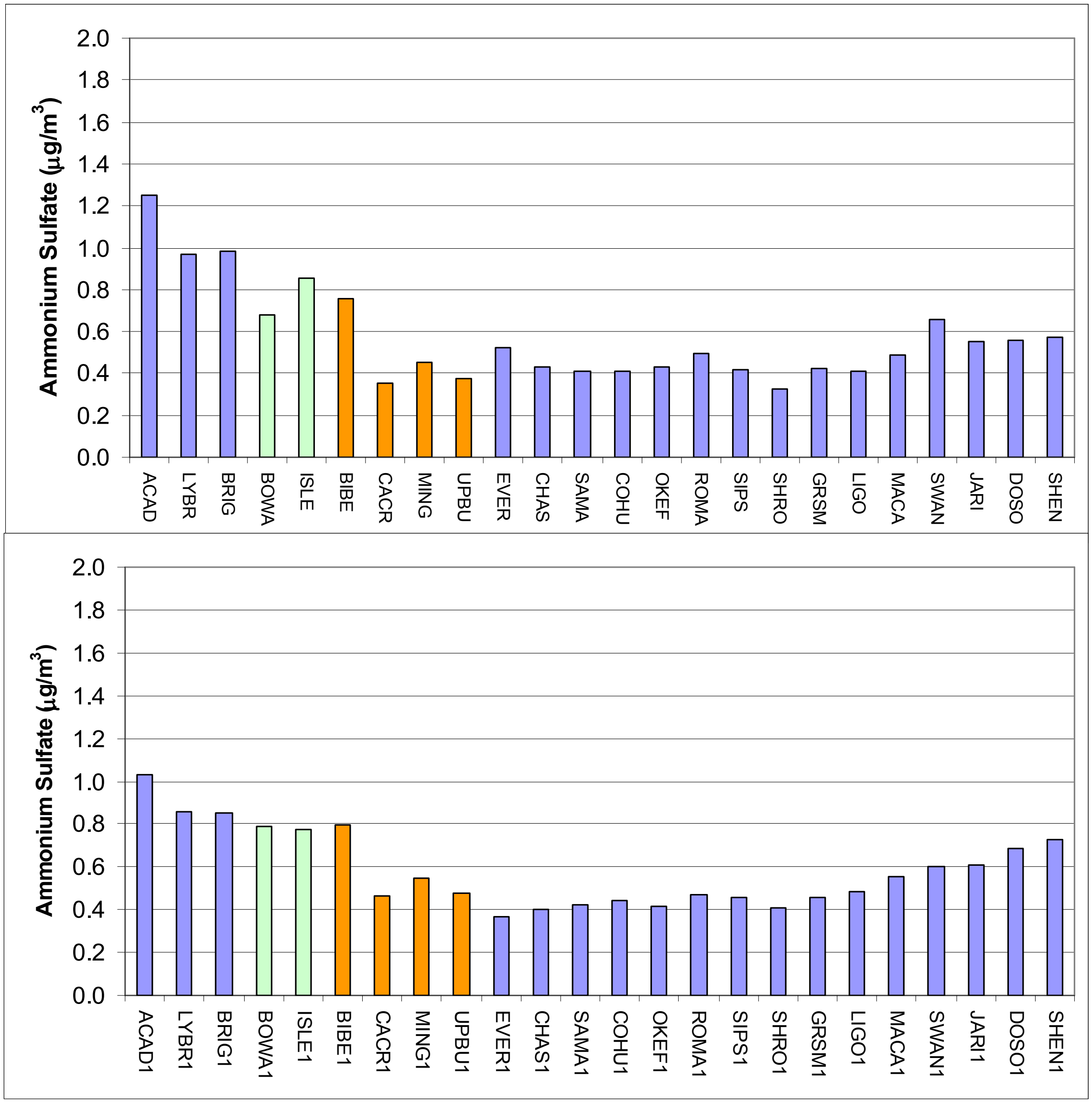
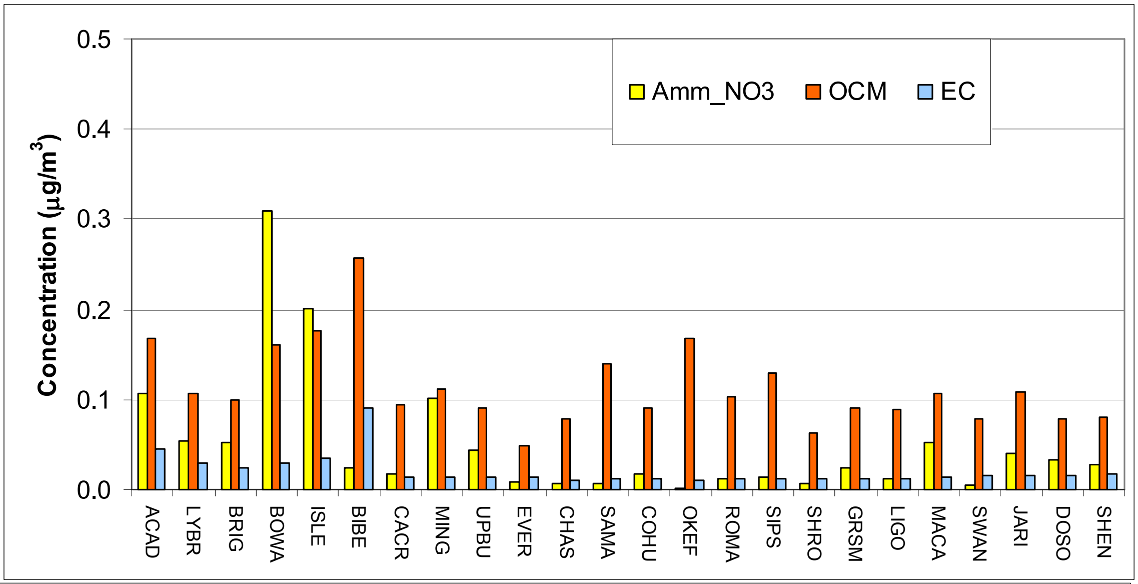


Figure 5-13. Comparison of EPRI Harvard GEOS-Chem global chemistry and CENRAP PSAT international source contributions to ammonium sulfate at Class I areas.



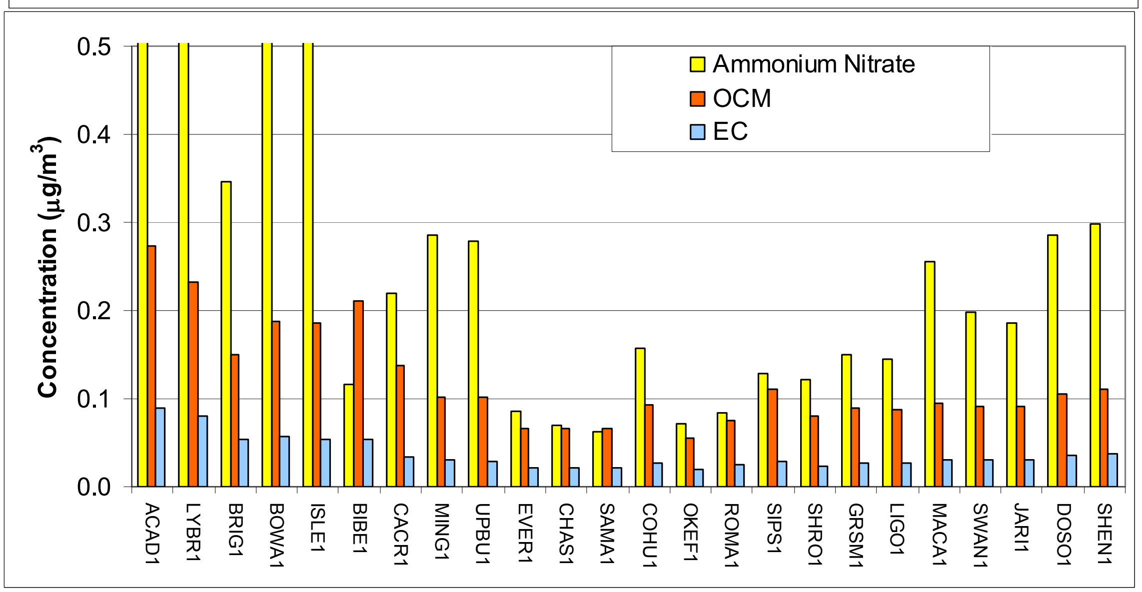


Figure 5-14. Comparison of EPRI Harvard GEOS-Chem global chemistry and CENRAP PSAT international source contributions to ammonium nitrate, organic carbon mass (OCM or OMC) and elemental carbon (EC) at Class I areas.

The EPRI technical brief used the VISTAS CMAQ runs to adjust the modeled 2018 visibility projections to eliminate the effect of international transport and compared them to the 2018 URP point. For the Boundary Waters, Voyageurs, Isle Royal and Seney Class I areas the standard 2018 visibility projections did not achieve the 2018 URP point. However, when the effect of transboundary pollutions was removed the 2018 URP point was essentially achieved or more than achieved at all four Class I areas.

5.7.1.2 CENRAP Results From Elimination International Transport

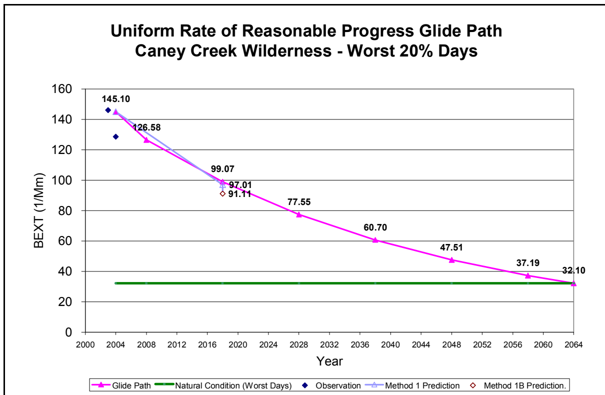
Because the elimination of the international sources from the 2018 visibility projections results in a portion of the total light extinction, then these comparisons with the 2018 URP points were done using extinction glidepaths and projections rather than deciview. In Section 5.2.1 we demonstrated that the level of achieving the 2018 URP point was almost identical at CENRAP Class I areas whether the linear deciview or curved extinction glidepaths were used. The PSAT source apportionment was used to determine the contribution to the projected extinction in 2018 due to international sources. As noted above, international sources were assumed to be due to anthropogenic emissions in Mexico and Canada and half of the Boundary Conditions.

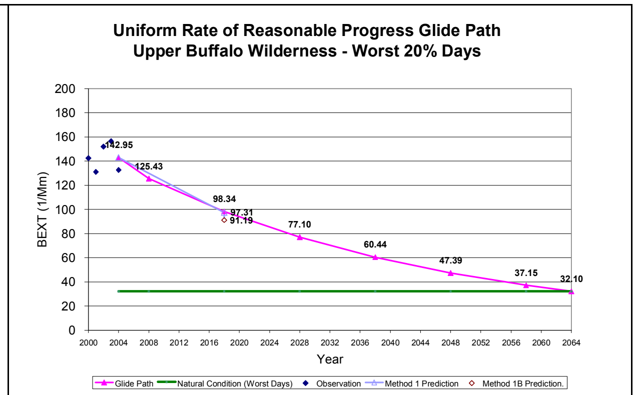
Figure 5-15 shows the standard CAMx extinction glidepaths and 2018 visibility projections and the 2018 visibility projections when the contributions of international sources is eliminated. CACR, which achieved the 2018 URP point by 104%, achieves it by even more when international sources are eliminated (117%). UPBU that barely achieved the 2018 URP point by 102% achieves it by 116% without international emissions.

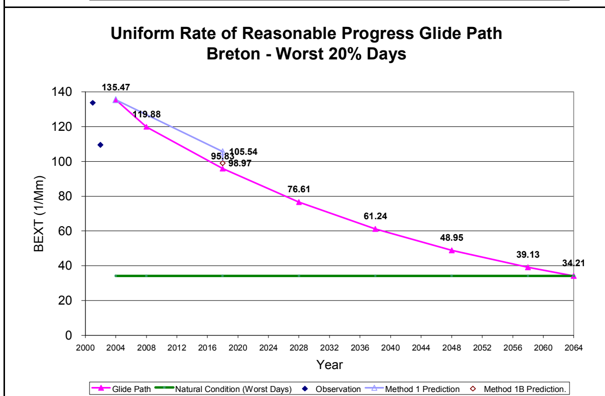
BRET comes up short of achieving the 2018 URP point when international emission are included (76%) as well as when they are eliminated (92%), although it is much closer (recall contributions of Gulf of Mexico to visibility impairment at BRET that is assumed in this analysis to be of U.S. origin). Eliminating international transport emissions makes of difference of meeting the 2018 URP point without them (120%) to not meeting it with them (64%) at BOWA. Similarly at VOYA the standard 2018 visibility projections do not achieve the 2018 URP point (54%), whereas it is achieved by a far margin when international sources are eliminated (132%).

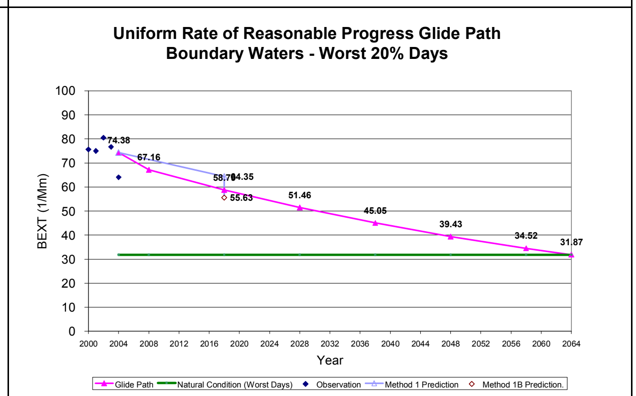
HEGL comes up short achieving the 2018 URP point when international sources are included (95%), but achieves it when they are eliminated (107%). Recall the standard CAMx deciview visibility projections barely achieved the URP point even when international emissions are included (Figure 5-12). MING achieves the 2018 URP point with (106%) and without (116%) international sources. WIMO does not achieve the 2018 URP point when international contributions are eliminated.

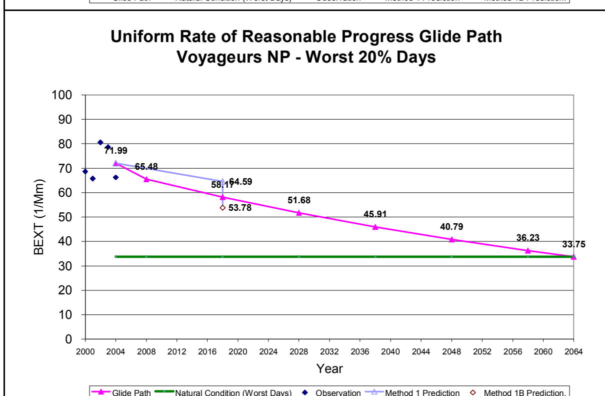
International sources have by far the largest effect at BIBE. Whereas the standard 2018 visibility projections only achieved 27% of the reductions needed to achieve the 2018 URP point, elimination of the international source contributions achieves 172% of the reduction needed. GUMO comes up short in achieving the 2018 URP point when international sources are included (31%), but achieves it when they are not (107%).

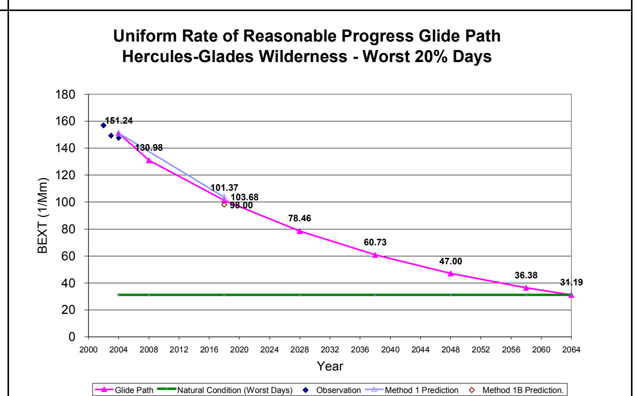

Uniform Rate of Reasonable Progress Glide Path
Caney Creek Wilderness - Worst 20% Days
BEXT (1/Mm)
Year
145.10
126.58
99.07
97.01
91.11
77.55
60.70
47.51
37.19
32.10
Glide Path
Natural Condition (Worst Days)
Observation
Method 1 Prediction
Method 1B Prediction.

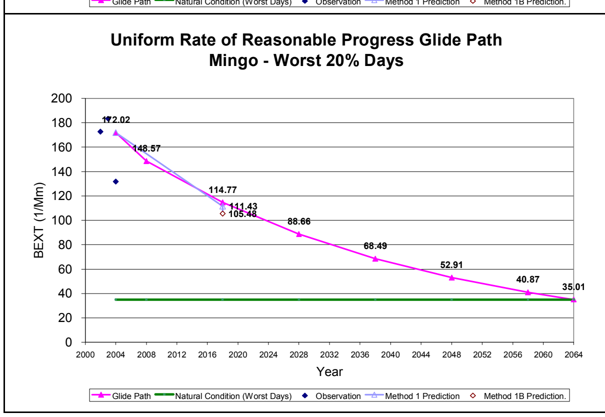

Uniform Rate of Reasonable Progress Glide Path
Upper Buffalo Wilderness - Worst 20% Days
BEXT (1/Mm)
Year
142.95
125.43
98.34
97.31
91.19
77.10
60.44
47.39
37.15
32.10
Glide Path
Natural Condition (Worst Days)
Observation
Method 1 Prediction
Method 1B Prediction.

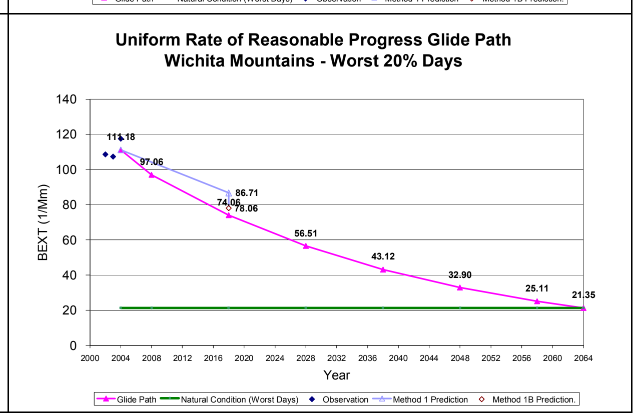

Uniform Rate of Reasonable Progress Glide Path
Breton - Worst 20% Days
BEXT (1/Mm)
Year
135.47
119.88
105.54
95.83
98.97
76.61
61.24
48.95
39.13
34.21
Glide Path
Natural Condition (Worst Days)
Observation
Method 1 Prediction
Method 1B Prediction.

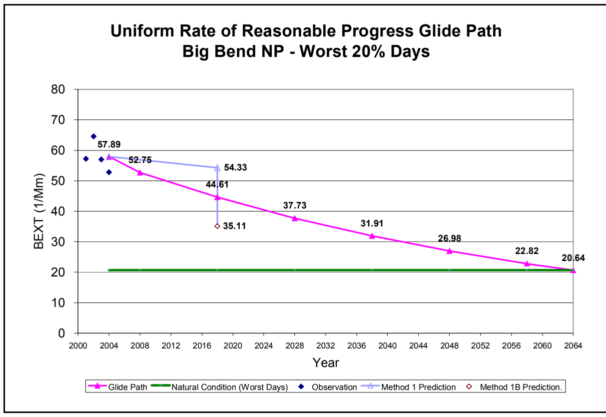

Uniform Rate of Reasonable Progress Glide Path
Boundary Waters - Worst 20% Days
BEXT (1/Mm)
Year
74.38
67.16
58.76
64.35
55.63
51.46
45.05
39.43
34.52
31.87
Glide Path
Natural Condition (Worst Days)
Observation
Method 1 Prediction
Method 1B Prediction.


Uniform Rate of Reasonable Progress Glide Path
Voyageurs NP - Worst 20% Days
BEXT (1/Mm)
Year
71.99
65.48
58.17
64.59
53.78
51.68
45.91
40.79
36.23
33.75
Glide Path
Natural Condition (Worst Days)
Observation
Method 1 Prediction
Method 1B Prediction.


Uniform Rate of Reasonable Progress Glide Path
Hercules-Glades Wilderness - Worst 20% Days
BEXT (1/Mm)
Year
151.24
130.98
101.37
103.68
98.00
78.46
60.73
47.00
36.38
31.19
Glide Path
Natural Condition (Worst Days)
Observation
Method 1 Prediction
Method 1B Prediction.


Uniform Rate of Reasonable Progress Glide Path
Mingo - Worst 20% Days
BEXT (1/Mm)
Year
172.02
148.57
114.77
111.43
105.48
88.66
68.49
52.91
40.87
35.01
Glide Path
Natural Condition (Worst Days)
Observation
Method 1 Prediction
Method 1B Prediction.


Uniform Rate of Reasonable Progress Glide Path
Wichita Mountains - Worst 20% Days
BEXT (1/Mm)
Year
111.18
97.06
86.71
74.06
78.06
56.51
43.12
32.90
25.11
21.35
Glide Path
Natural Condition (Worst Days)
Observation
Method 1 Prediction
Method 1B Prediction.



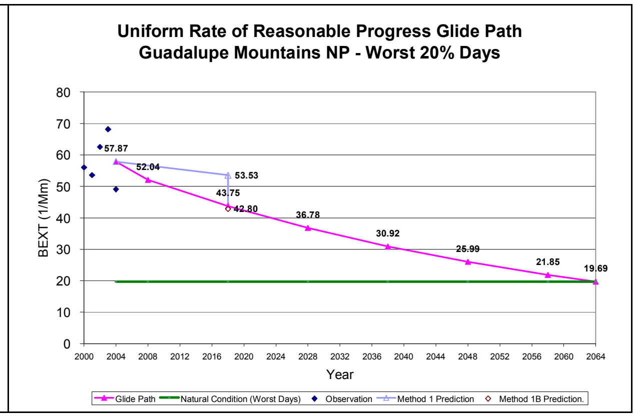


Figure 5-15. Elimination of international sources from 2018 visibility projections and comparison with 2018 URP point at CENRAP Class I areas.

5.7.2 Glidepaths Based on Controllable Extinction

Another alternative glidepath that was examined using the CAMx PSAT source apportionment results was based on the U.S. anthropogenic emissions contributions to visibility impairment on the worst 20 percent days at the CENRAP Class I areas. The RHR strives to achieve "natural visibility conditions" by 2064 and defines natural conditions as conditions that would exist "in the absence of human caused impairment". As shown above, anthropogenic emissions from international sources contribute significantly at many of the CENRAP Class I areas making the RHR objective not practical if contributions from such sources are not reduced. Given that states and EPA have no jurisdiction over international sources then we can not assume they will be controlled and have therefore mostly held them constant at 2002 levels. For such Class I areas with high contributions from international sources the comparison with the 2018 URP point is not very meaningful since the 2018 URP assumes such sources will be reduced. A more meaningful comparisons would be to focus on the U.S. man-made contributions to visibility impairment at the Class I areas and develop a URP glidepath and 2018 URP point that is aimed at eliminating the U.S. anthropogenic emissions contributions to visibility impairment by at Class I areas for the worst 20 percent days, in 2064.

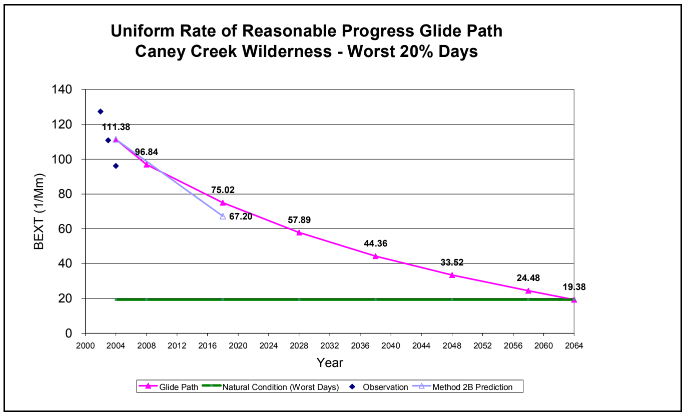
The CAMx 2002 base case PSAT PM source apportionment results were processed to identify the portion of the 2000-2004 Baseline extinction that was due to U.S. anthropogenic emissions (i.e., man-made sources). The contributions of source groups that included on-road mobile, non-road mobile, elevated point sources, low-level point sources and area sources from the PSAT source regions covering the U.S. states and Gulf of Mexico (Figure 5-7) were assumed to make up the U.S. anthropogenic contributions (i.e., excluding the Natural source category, all sources from the Mexico and Canada source regions and boundary conditions). Note that off-shore marine emissions in the Pacific and Atlantic Oceans and Gulf of Mexico were included in the U.S. anthropogenic emissions definition because they were in source regions associated with states or the Gulf of Mexico. As off-shore marine emissions may not be controllable by U.S. agencies and they were assumed to remain unchanged going from 2002 to 2018, then the 2018 visibility projections for the U.S. anthropogenic component are overstated.

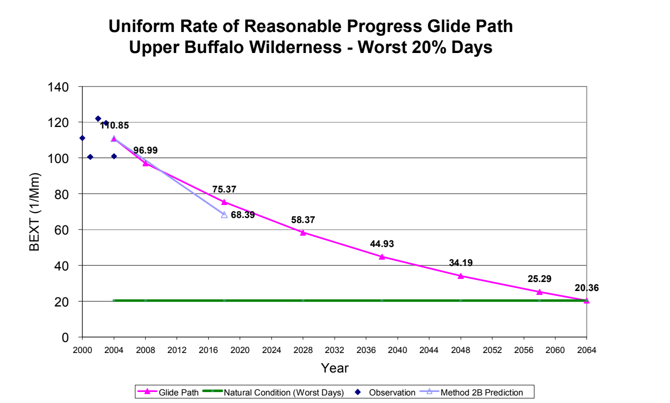
The 2064 objective for the U.S. anthropogenic emissions glidepath would be no contributions on the worst 20 percent days. This does not mean the 2064 U.S. anthropogenic extinction objective is zero, rather the U.S. anthropogenic plus natural background is less than the Natural Conditions for the worst 20 percent days. The PSAT results were used to define the natural background contributions on the current worst 20 percent days which was subtracted from the EPA default Natural Conditions to obtain the 2064 objective for the U.S. anthropogenic emissions contributions. Here the PSAT derived natural background was defined as contributions from the Natural source category plus half of the boundary conditions.

Figure 5-16 displays the U.S. anthropogenic emissions extinction glidepaths and comparison with the 2018 visibility projections for extinction due to U.S. anthropogenic emissions on the worst 20 percent days. As seen by the standard linear deciview glidepaths discussed in Chapter 4, the U.S. anthropogenic emissions 2018 URP point is achieved by a wide margin at the four Class I areas in Arkansas and Missouri (CACR, UPBU, HRGL and MING). BRET that achieved 94% of the 2018 URP point obtains similar results using the U.S. anthropogenic emissions glidepath achieving 96% of the 2018 URP point. As discussed above, the inclusion of the off-shore marine emissions in the U.S. anthropogenic emissions will greatly affect the BRET Class I area so that actual reduction in U.S. anthropogenic emissions extinction would be greater and may even achieve the 2018 URP point.

The BOWA and VOYA northern Minnesota Class I areas achieved, respectively, 69% and 53% of the 2018 URP point using the standard EPA default deciview glidepaths and projection techniques (Figure 4-4). Using the U.S. anthropogenic glidepaths BOWA and VOYA achieve 92% and 86% of the 2018 point, respectively (Figure 5-16). WIMO that came up approximately 40% short of achieving the 2018 URP point using the deciview glidepath comes up under 20% short using the U.S. anthropogenic emissions glidepath.

The two Texas Class I areas also come up short in achieving the 2018 URP point using the U.S. anthropogenic emissions glidepaths, but not as short as when the linear deciview glidepaths are used. BIBE increases from 26% to 67% and GUMO increases from 34% to 49%. One reason these two Class I areas fail to achieve the 2018 point for U.S. anthropogenic emissions is because of the high contributions of Soil and CM and little change in precursor emissions of these species between 2002 and 2018.





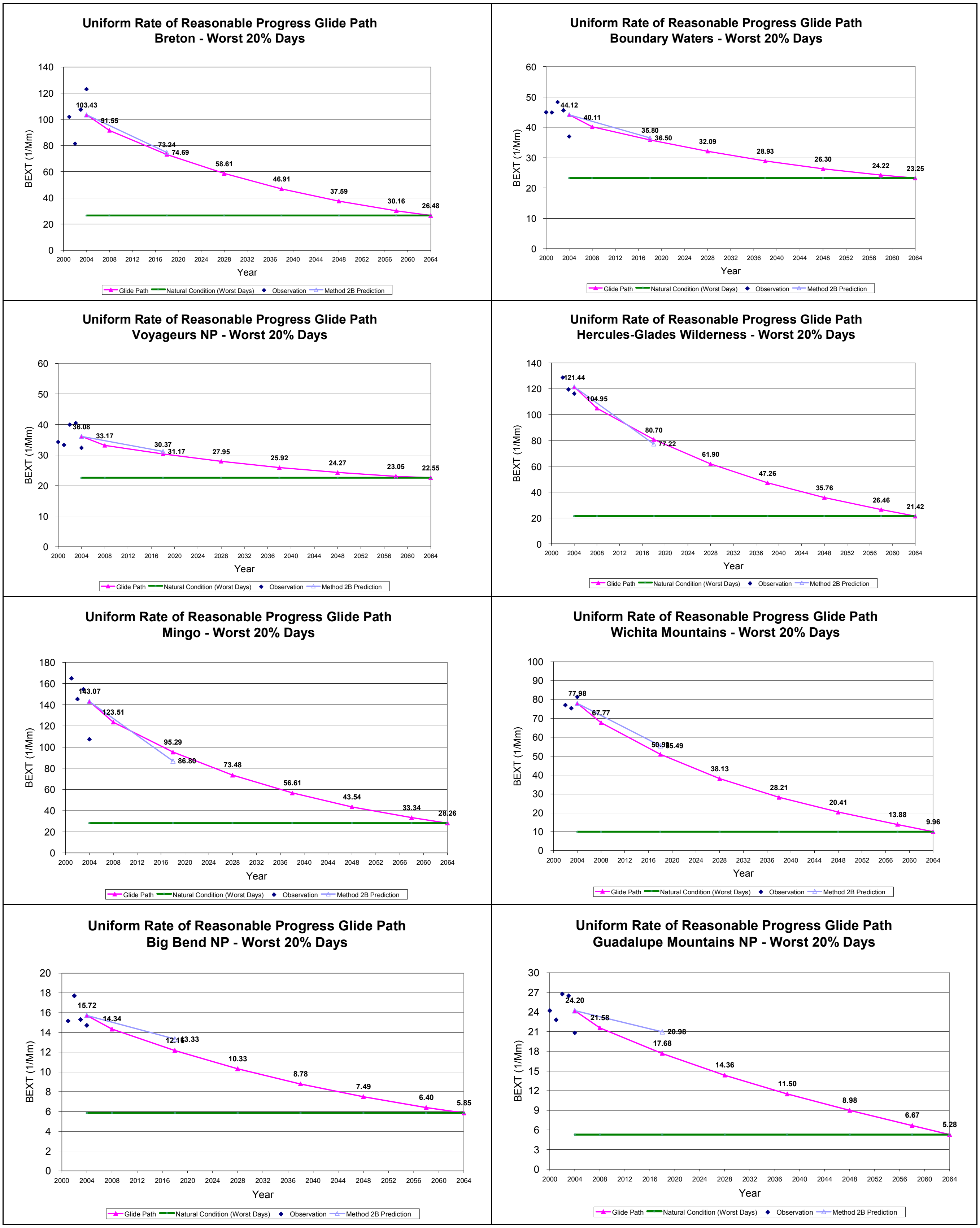


Figure 5-16. Glidepaths and 2018 visibility projections based on visibility due to U.S. anthropogenic emissions at CENRAP Class I areas.

5.8 Visibility Trends

Figure 5-17 displays trends in visibility impairment at the CENRAP Class I areas using the period of record of measurements at the associated IMPROVE monitor and the new IMPROVE equation. These trends include trends for the worst 20 percent days, the best 20 percent days and all IMPROVE sampled days. The EPA guidance procedures were used to construct the worst and best 20 percent days that includes a minimum data capture requirement, whereas no such minimum data capture was applied when looking at the "annual average" of all IMPROVE sampled days trends. So care must be taken when analyzing trends for the all sampled IMPROVE days trends as there could be large missing periods with high or low extinction that are not being account for. The TSS website was used to calculate the visibility trends at the CENRAP Class I areas that includes IMPROVE data from start of recording through 2004 and includes no data filling.

Trends in visibility at CACR has three years of data (2002-2004) for the worst and best 20 percent days and fives years for the IMPROVE sampled days trends. Although it is hard to come to any conclusions regarding trends with three years of data, there does seem to be a general downward trend, that is also supported by the five year trend in the IMPROVE sampled days.

A much longer trend plot is available for UPBU that includes 12 years of data for the worst and best 20 percent days (Figure 5-17b). Although there is a lot of a year-to-year variation in the visibility trends with cleaner years occurring in 1997, 2001 and 2004, there does appear to be a slight trend toward improving visibility at UPBU.

There is insufficient data to calculate the worst or best 20 percent days visibility for any year at the BRET Class I area so only the IMPROVE sampled days trends are presented (Figure 5-17c). The trends at BRET are inconclusive and given the large amounts of missing data at this site it is difficult to interpret the results.

There is also a lot of missing years in the worst and best 20 percent days for the BOWA Class I area making it difficult to interpret (Figure 5-17d). But visibility appears to be more impaired in the early 1990s than in more current years so improvements have been seen. VOYA has five years of valid data and shows worsening visibility for 2000-2003, and then improved visibility in 2004. It is unclear whether the 2004 improved visibility is a trend or just due to variations in meteorology so no conclusions can be drawn.

Although a downward trend in visibility impairment appears to be occurring at the two Missouri Class I areas (Figure 5-17f-g), given that there are only three years available for HEGL and lots of missing data for MING these trends are inconclusive.

Three years (2002-2004) of visibility trends for the worst and best 20 percent days are available for WIMO (Figure 5-17h). The most impaired year from the three years for the worst 20 percent days is the most recent (2004). Again, the time period is too short to draw any conclusions on trends in visibility at WIMO.

The two Texas Class I areas have a relatively long period of record. There is a lot of year-to-year variability in the visibility measurements that make interpreting the trends difficult. 1998 appears to be an anomalously high visibility impairment year at BIBE and due to the much higher OMC extinction indicates that the year was likely impacted by smoke from fires. GUMO has lots of year to year variability in CM and Soil which are likely due to occurrences of impacts due to wind blown dust. Even taking Soil and CM out of the interpretation it is difficult to interpret ay trend in visibility at the two Texas Class I areas. The higher visibility impairment in 1998 and 1999 suggests a downward trend but that may be just due to more adverse meteorological and natural emissions (e.g., wildfires) in these two years than any real long term trend.

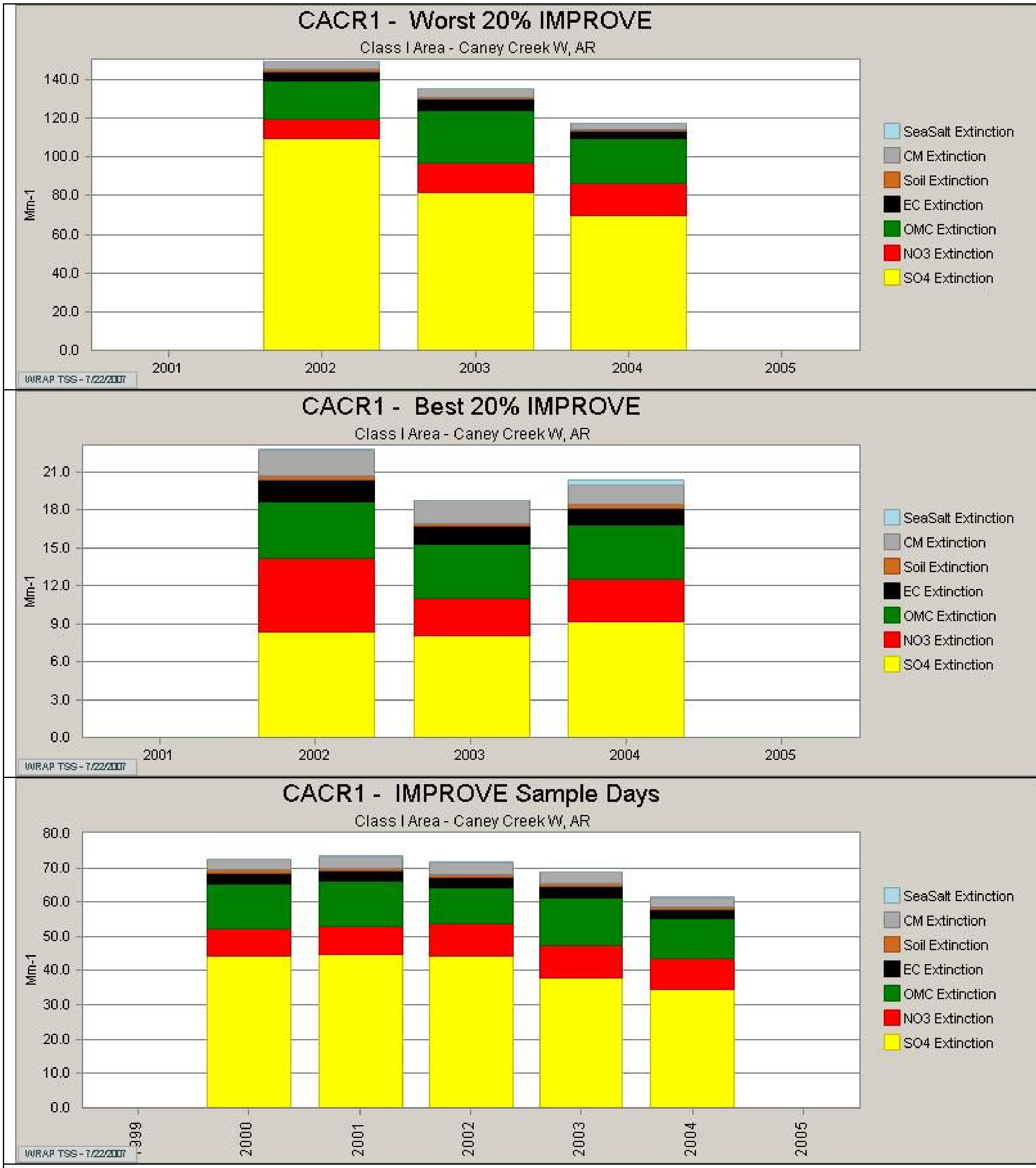


Figure 5-17a. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Caney Creek (CACR), Arkansas for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

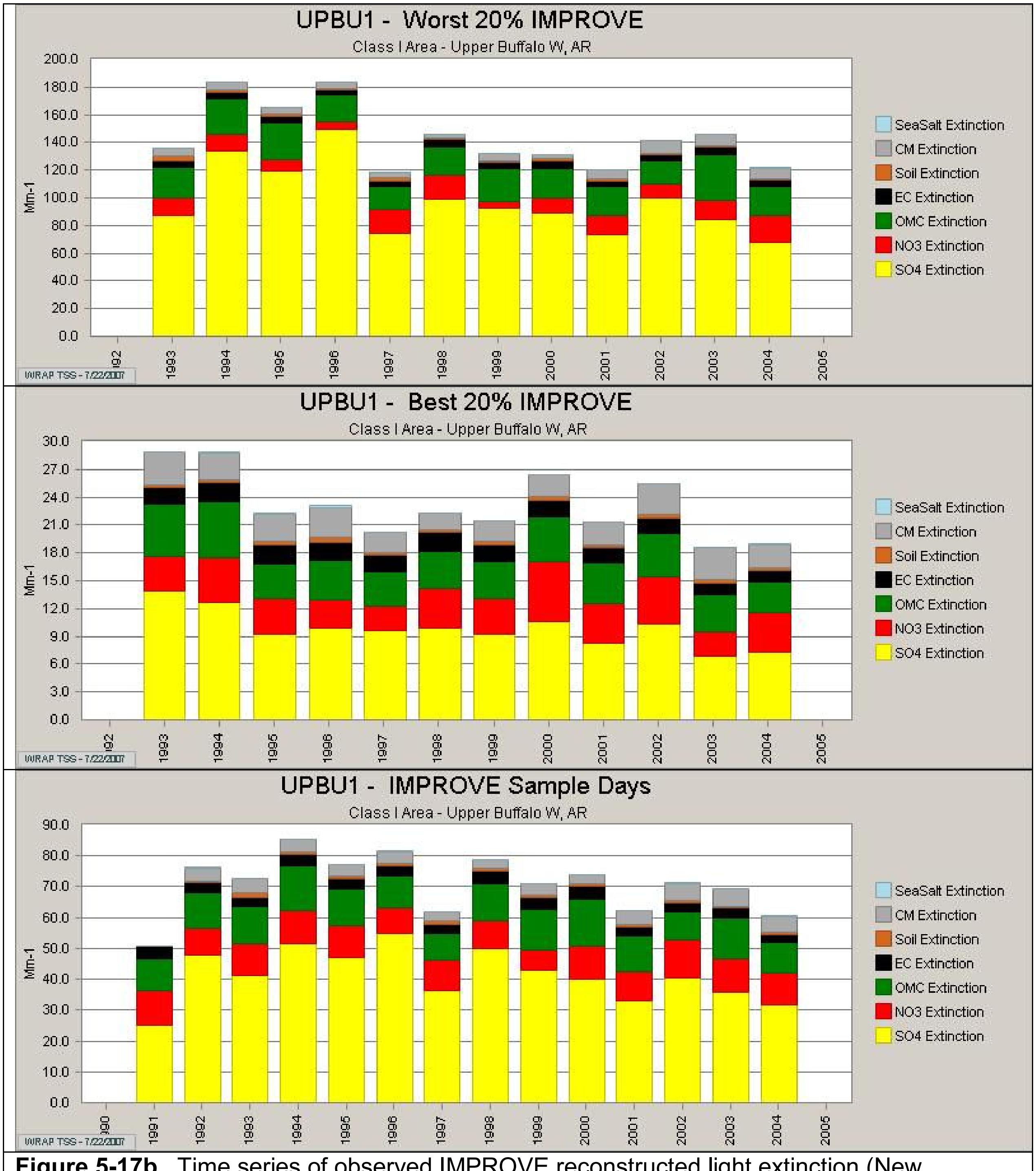


Figure 5-17b. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Upper Buffalo (UPBU), Arkansas for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

Insufficient Data to Calculate Best 20 Percent days at BRET

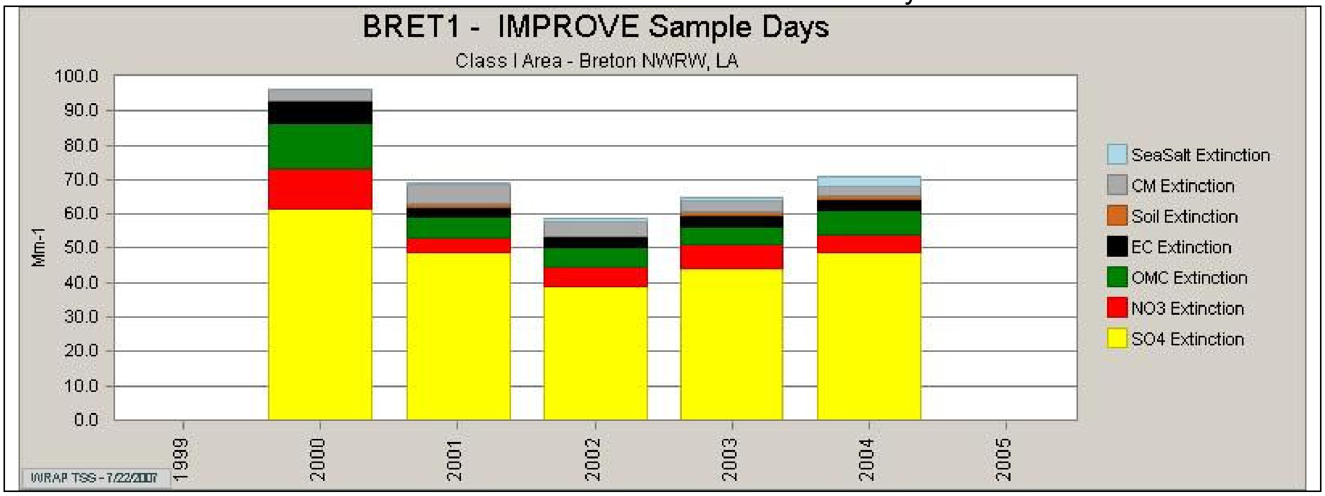


Figure 5-17c. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Breton Island (BRET), Louisiana for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

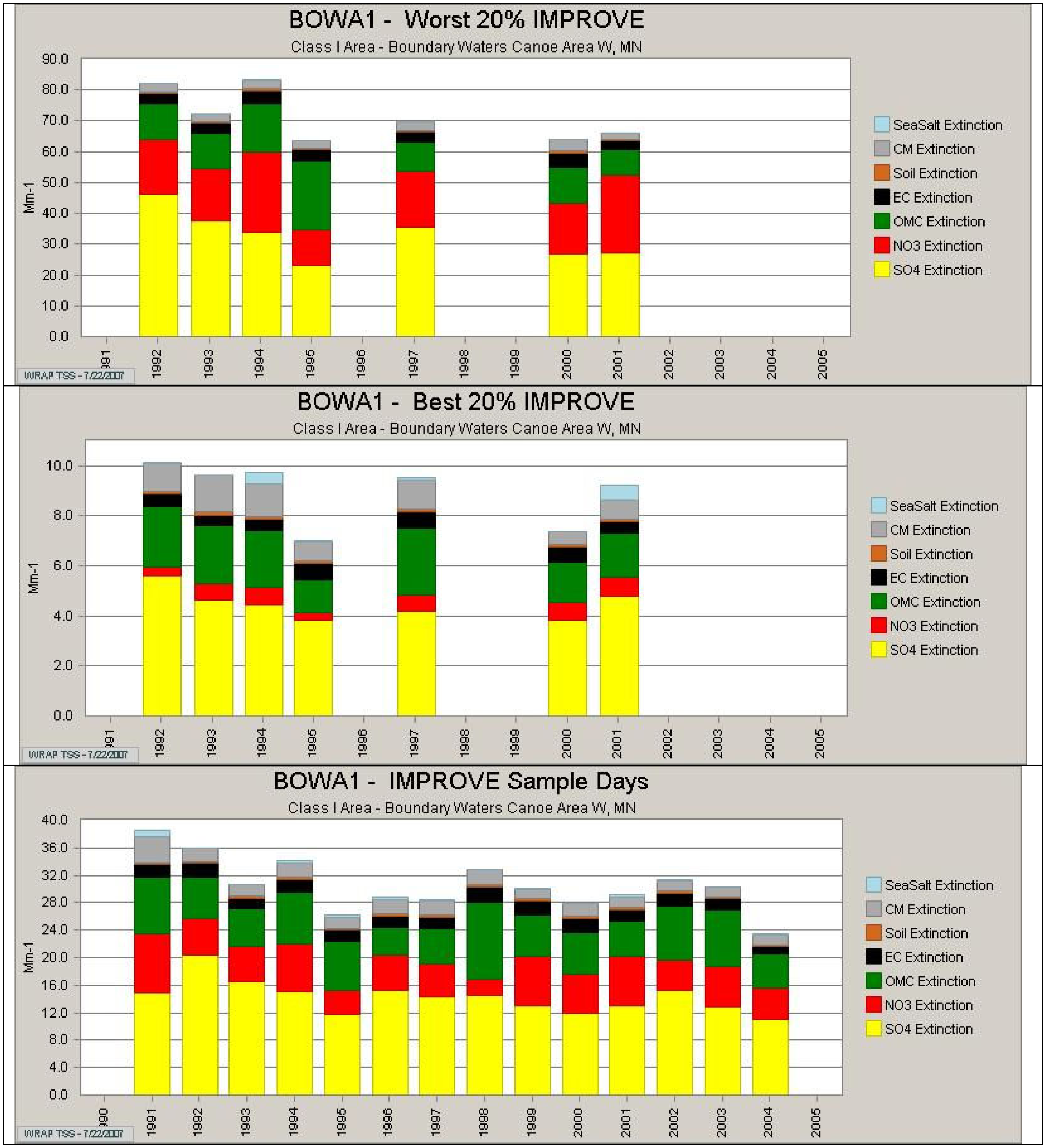


Figure 5-17d. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Boundary Waters (BOWA), Minnesota for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

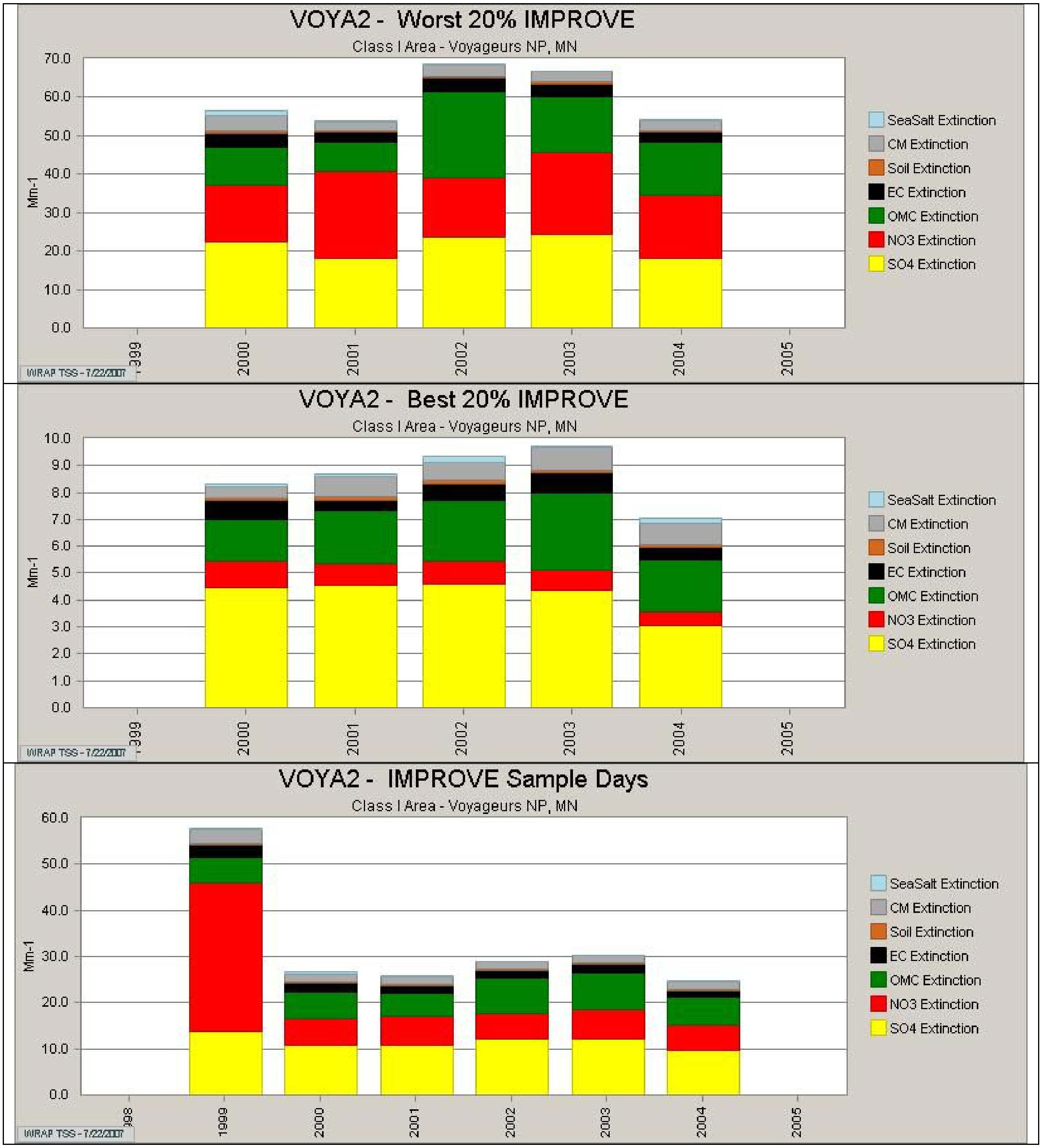


Figure 5-17e. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Voyageurs (VOYA), Minnesota for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

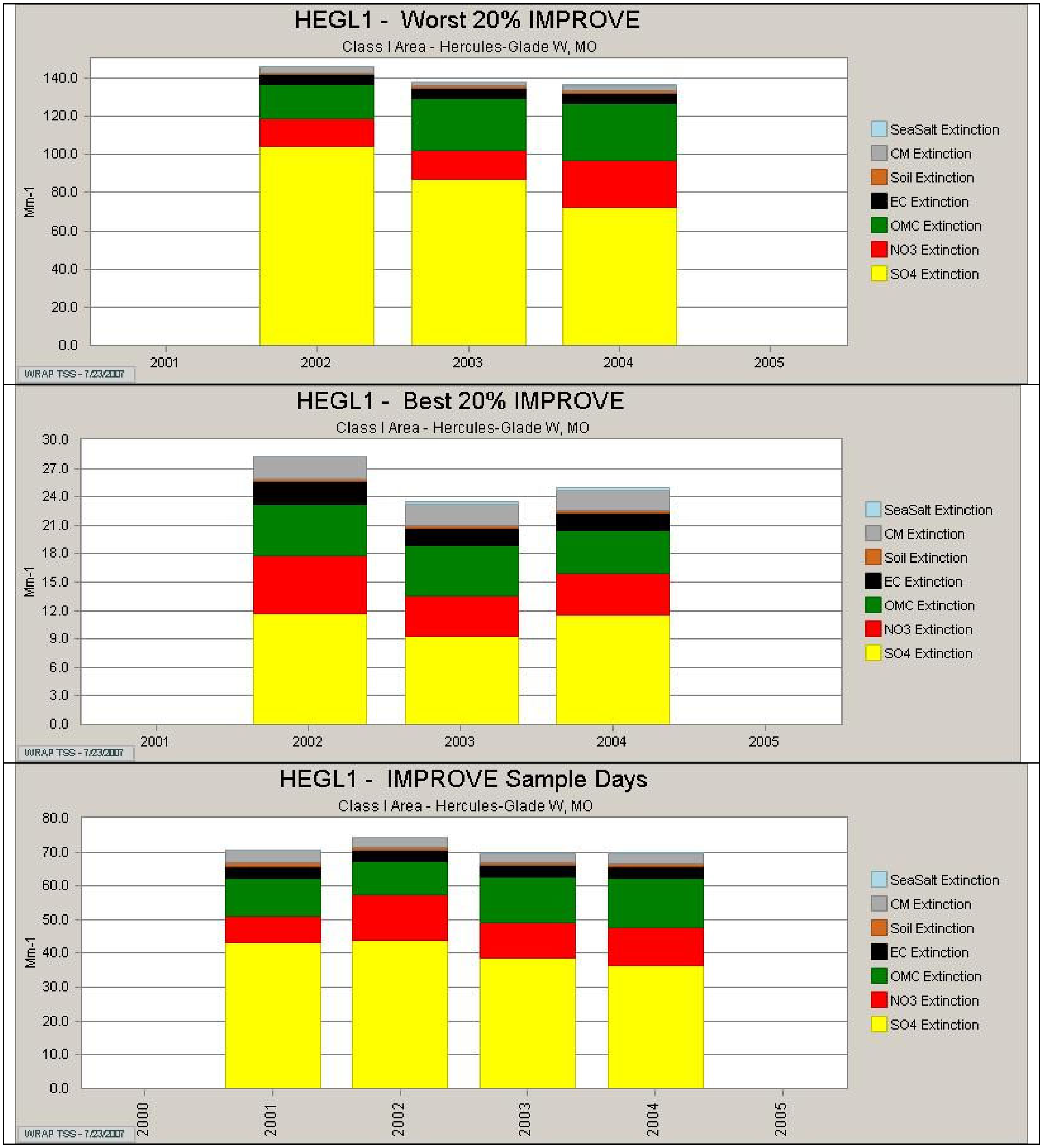


Figure 5-17f. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Hercules Glade (HEGL), Missouri for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

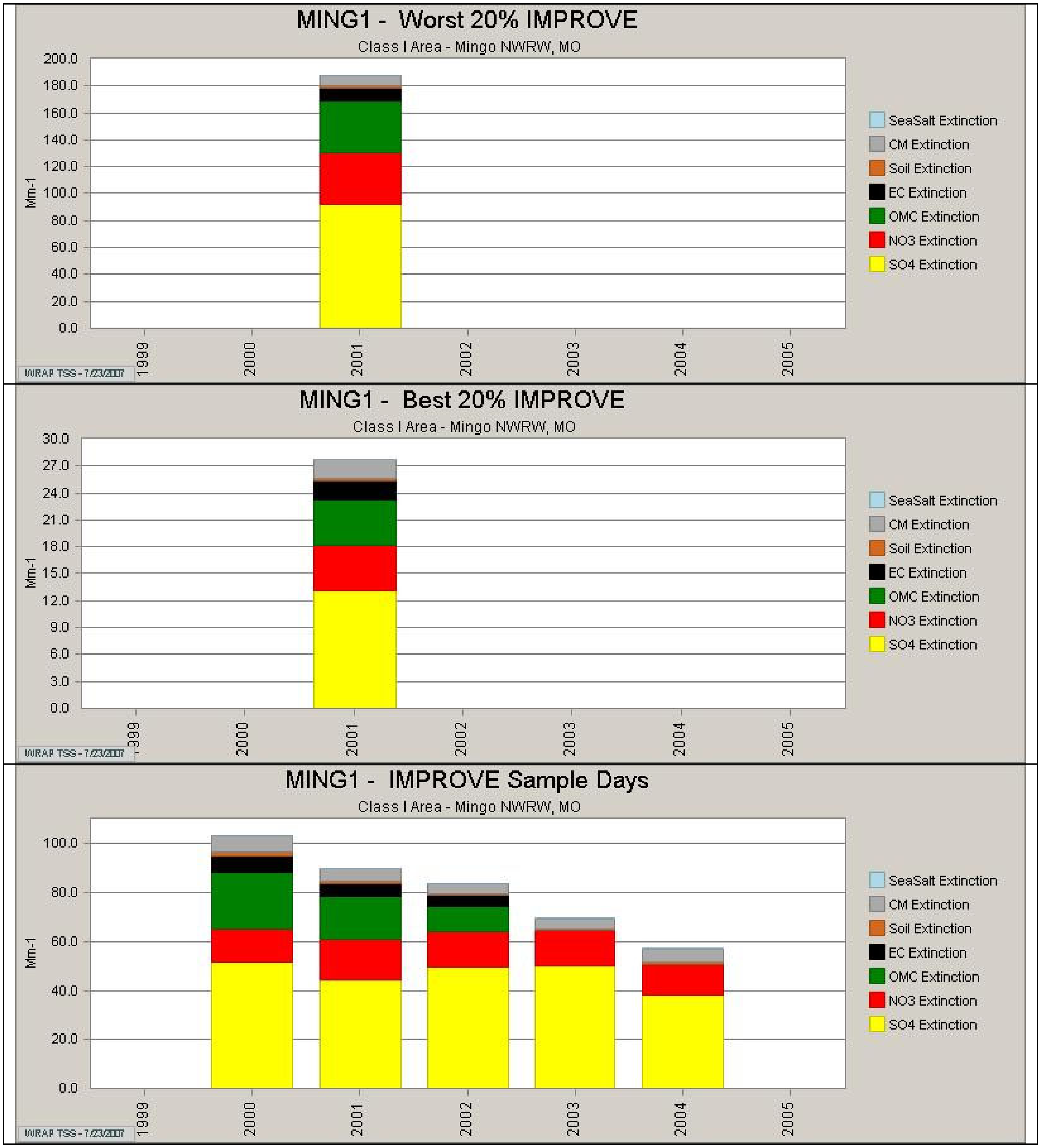


Figure 5-17g. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Mingo (MING), Missouri for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

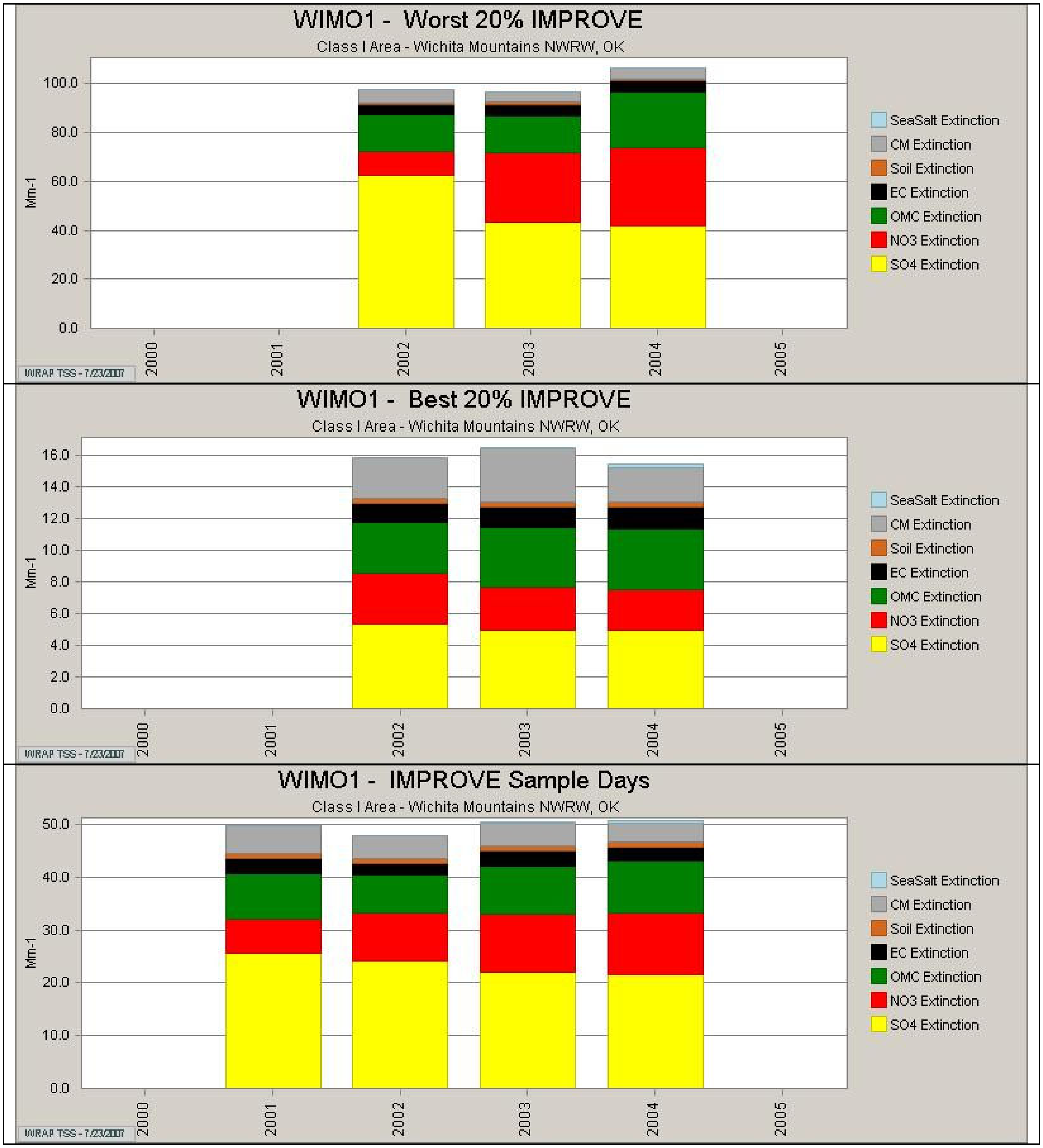


Figure 5-17h. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Wichita Mountains (WIMO), Oklahoma for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

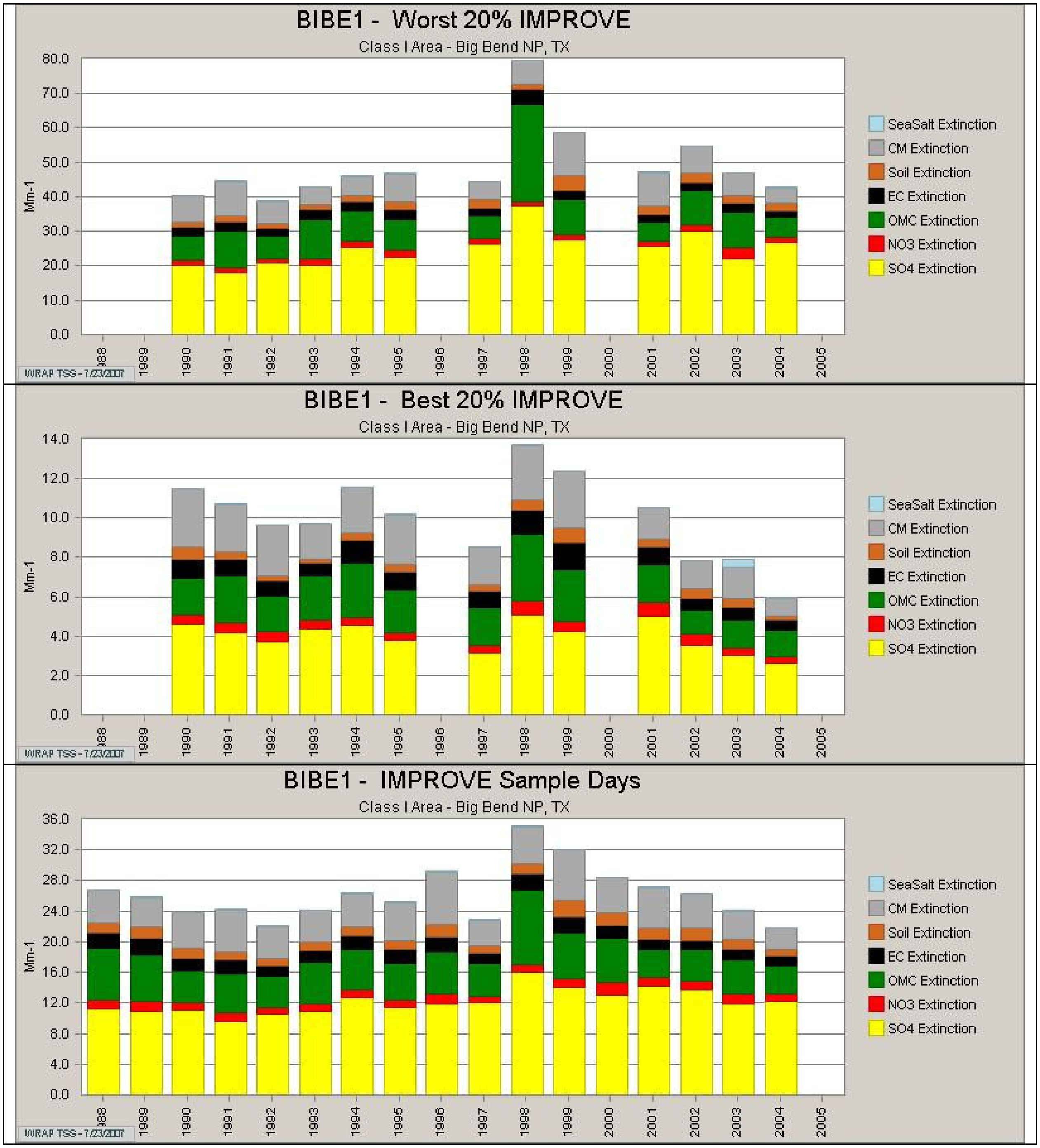


Figure 5-17i. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Big Bend (BIBE), Texas for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

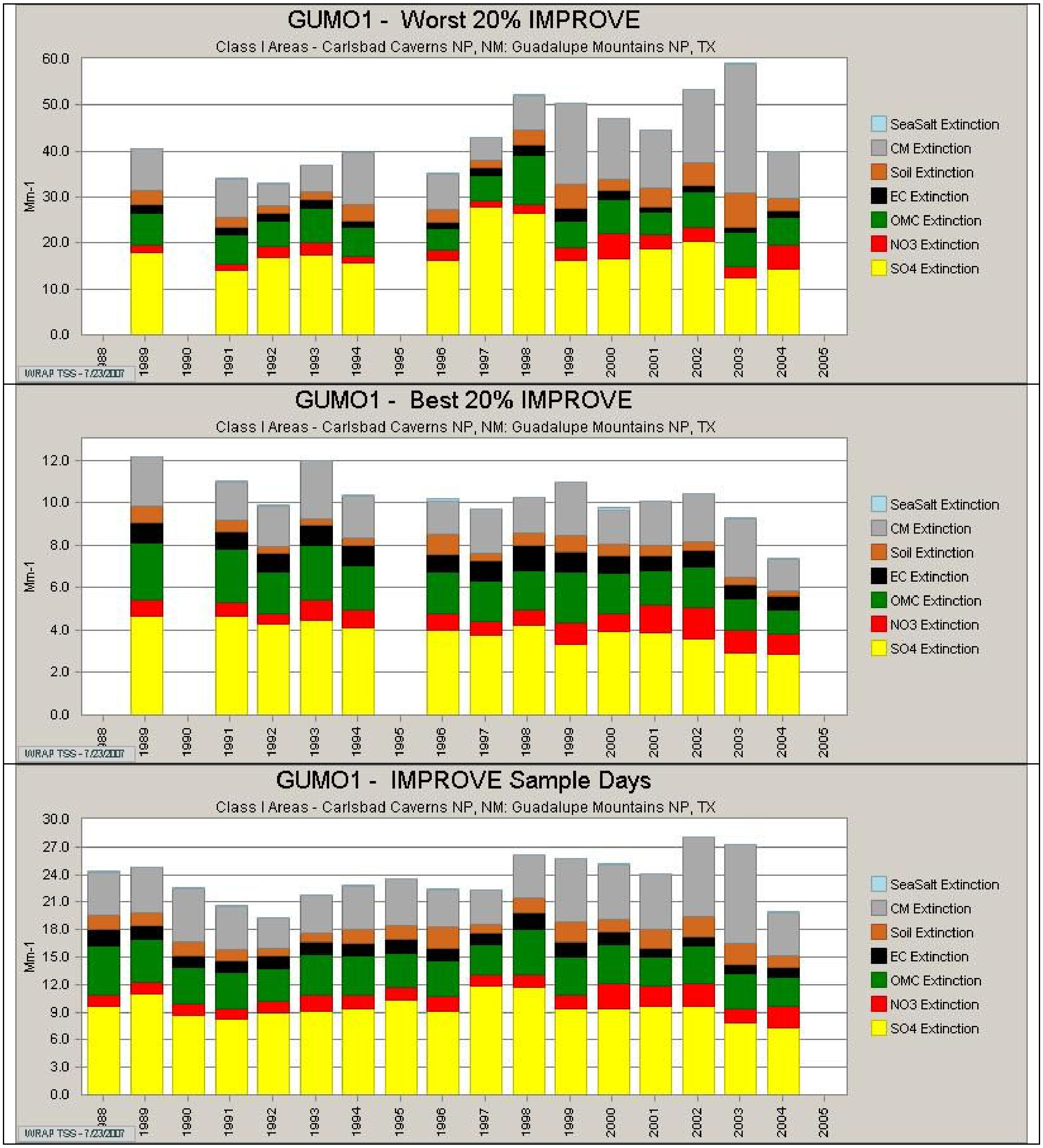


Figure 5-17j. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Guadalupe Mountains (GUMO), Texas for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.